

HUMAN PEROXISOME PROLIFERATOR ACTIVATED RECEPTOR GAMMA**(PPAR γ) GENE REGULATORY SEQUENCES AND USES THEREFOR****I. FIELD OF THE INVENTION**

5 This invention relates to DNA sequences that regulate expression of human peroxisome proliferator activated receptor (PPAR) genes, particularly PPAR γ genes. This invention further relates to methods for identifying agents useful for treatment of diseases and pathological conditions affected by PPAR, and agents and compositions identified using such screening method.

II. BACKGROUND OF THE INVENTION

10 Peroxisome proliferator activated receptors (PPARs) constitute a subfamily of the nuclear hormone receptors. Three distinct PPARs, termed α , δ (also called β , NUC-1 or FAAR) and γ , each encoded by a separate gene and showing a distinct tissue distribution pattern, have been described [Reviews: Desvergne, B. and Wahli, W., *Birkhauser*. 1: 15 142-176 (1994); Green, S., *Mutation Res.* 333: 101-109 (1995); Schoonjans, K. *et al.*, *Biochem. Biophys. Acta.* 1302: 93-109 (1996); Schoonjans, K. *et al.*, *J. Lipid Res.* 37: 907-925 (1996)]. Although it was known that PPARs are activated by a wide variety of chemicals including fibrates, phthalates and fatty acids, PPARs were initially considered 20 orphan receptors, since no direct binding of these compounds to the receptors could be demonstrated.

Activated PPARs heterodimerize with retinoid X receptors (RXRs), another subfamily of nuclear hormone receptors, and alter the transcription of target genes after binding to PPAR response elements (PPREs). A PPRE typically contains a direct repeat 25 of the nuclear receptor hexameric DNA core recognition motif, an arrangement termed DR-1 when recognition motifs are spaced by 1 nucleotide [Schoonjans, K. *et al.*, *J. Lipid Res.* 37: 907-925 (1996)].

Recently, ligands that induce the transcriptional activity of PPAR α (fibrates and leukotriene B₄) and γ (prostaglandin J derivatives and thiazolidinediones) have been identified [Devchand, P. R. *et al.*, *Nature* 384: 39-43 (1996); Kliewer, S. A. *et al.*, *Cell* 83: 813-819 (1995); Forman, B. M. *et al.*, *Cell* 83: 803-812 (1995); Lehmann, J. M. *et al.*, *J. Biol. Chem.* 270: 12953-12956 (1995)].

Numerous PPAR target genes have been identified so far [Review: Schoonjans, K. *et al.*, *Biochem. Biophys. Acta.* 1302: 93-109 (1996)], and additional target genes continue to be identified [Hertz, R. *et al.*, *Biochem. J.* 319: 241-248 (1996); Ren, B. *et al.*, *J. Biol. Chem.* 271: 17167-17173 (1996)]. Because they are activated by various fatty acid metabolites as well as several drugs used in the treatment of metabolic disorders, PPARs are key messengers responsible for the translation of nutritional, pharmacological and metabolic stimuli into changes in gene expression.

PPAR γ was the first PPAR for which ligands were identified. In rodents, PPAR γ was thought to be confined to adipose tissue. However, low levels of PPAR γ expression were detected in other tissues. This led to the suggestion that PPAR γ is a key factor triggering adipocyte differentiation, a hypothesis later confirmed [Spiegelman, B. M. and Flier, J. S., *Cell* 87: 377-389 (1996)]. It is now known that several transcription factors including the nuclear receptor PPAR γ (6, 7), the family of CCAATT enhancer binding proteins (C/EBP)1 (8-13) and the basic helix-loop-helix leucine zipper transcription factor ADD1/SREBP1 (14, 15) orchestrate the adipocyte differentiation process (for reviews, see Refs. 1, 3, 16-18).

Two isoforms of PPAR γ (PPAR γ 1 and PPAR γ 2 that differ by an extra 30 amino acids at the N-terminus) have been identified in mice (Tontonoz, *et al.* *Genes & Development* 8:1224-1234 (1994)). Two forms of human PPAR γ , γ 1 and γ 2, have been identified; PPAR γ 1 has been shown to be the most common form in humans [Mukherjee, R. *et al.*, *J. Biol. Chem.* 272: 8071-8076 (1997)]. PPAR γ 2 is expressed at high levels specifically in adipose tissue and is induced early in the course of differentiation of 3T3-L1 preadipocytes to adipocytes. Overexpression and activation of PPAR γ protein stimulates adipose conversion in cultured fibroblasts (Tontonoz, *et al.* *Cell* 79:1147-1156

(1994)). In addition, PPAR γ together with C/EBP α can induce transdifferentiation of myoblasts into adipocytes (19). Activation of PPAR γ is sufficient to turn on the entire program of adipocyte differentiation (Lehmann, *et al. J. Biol. Chemistry* 270:12953-12956 (1995)).

5 PPREs have been identified in several genes that play crucial roles in adipocyte differentiation, most of them affecting lipid storage and control of metabolism. Examples are fatty acid binding protein (aP2) [Tontonoz, P. *et al., Genes Dev.* 8: 1224-1234 (1994)], phosphoenolpyruvate carboxykinase (PEPCK) [Tontonoz, P. *et al., Mol. Cell. Biol.* 15: 351-357 (1995)], Acyl CoA Synthase (ACS) [Schoonjans, K. *et al., Eur. J. Biochem.* 216: 615-622 (1993); Schoonjans, K. *et al., J. Biol. Chem.* 270: 19269-19276 (1995)], and
10 lipoprotein lipase (LPL) [Schoonjans, K. *et al., EMBO J.* 15: 5336-5348 (1996)], all of which are regulated by PPAR γ .

Recently, prostaglandin J2 (PGJ2) was shown to be a naturally occurring ligand [Forman, B. M. *et al., Cell* 83: 803-812 (1995); Kliewer, S. A. *et al., Cell* 83: 813-819
15 (1995)] and the anti-diabetic thiazolidinediones (TZDs) [Forman, B. M. *et al., Cell* 83: 803-812 (1995); Lehmann, J. M. *et al., J. Biol. Chem.* 270: 12953-12956 (1995)] were shown to be synthetic ligands for PPAR γ . The identification of PGJ2 and TZDs as PPAR γ ligands corroborates the earlier observation that both prostanoids and TZDs are potent inducers of adipose differentiation programs [Gaillard, D. *et al., Biochem. J.* 257: 389-397
20 (1989); Negrel, R. *et al., Biochem. J.* 257: 399-405 (1989); Forman, B. M. *et al., Cell* 83: 803-812 (1995); Kliewer, S. A. *et al., Cell* 83: 813-819 (1995); Aubert, J. *et al., FEBS Lett.* 397: 117-121 (1996)]. TZDs are currently being developed as insulin sensitizers for the treatment of non-insulin dependent diabetes mellitus (NIDDM) [Reviews: Hulin, B. *et al., Current Pharm. Design* 2: 85-102 (1996); Saltiel, A. R. and Olefsky, J. M., *Diabetes*
25 45: 1661-1669 (1996)]. Interestingly, their relative potency to activate PPAR γ *in vitro* correlates well with their anti-diabetic potency *in vivo*, suggesting that PPAR γ mediates their anti-diabetic effect [Berger, J. *et al., Endocrinology* 137: 4189-4195 (1996); Willson, T. M. *et al., J. Med. Chem.* 39: 665-668 (1996)]. These observations define the role of
30 PPAR γ in adipose differentiation and a role in glucose and lipid metabolism.

Although many PPARs have been isolated and their cDNAs have been cloned from various species (International Patent publication nos. WO 96/23884, WO96/01430, WO95/11974, Elbrecht, A. *et al.*, *Biochem. Biophys. Res. Comm.* 224: 431-437 (1996), Greene, M.E. *et al.*, *Gene Expression* 4: 281-299 (1995), Aperlo, C. *et al.*, *Gene* 162: 297-302 (1995), Sher, T. *et al.*, *Biochemistry* 32: 5598-5604 (1993), Isseman, *et al.* *Nature* 347:645-650 (1990); Dreyer, *et al.*, *Cell* 68:879-887 (1992); Gottlicher, *et al.* *Proc. Natl. Acad. Sci. USA.* 89:4653-4657 (1992); Sher, *et al.* *Biochemistry* 32:5598-5604 (1993); and Schmidt, *et al.* *Mol. Endocrinol.* 6:1634-16414-8 (1992); Tontonoz, *et al.* *Genes & Development* 8:1224-1234 (1994); Kliewer, *et al.* *Proc. Natl. Acad. Sci.* 91:7355-7359 (1994); Chen, *et al.* *Biochem. and Biophys. Res. Com.* 196:671-677 (1993)), information regarding the regulation of PPAR expression is very limited (see, *e.g.* Wu, Z. *et al.*, *Mol. Cell. Biol.* 16(8): 4128-4136 (1996), Zhu, Y. *et al.*, *Proc. Natl. Acad. Sci. USA* 92: 7921-7925 (1995), Mukherjee, R. *et al.*, *J. Steroid Biochem.* 51(3/4): 157-166 (1994)). In particular, the regulatory regions controlling the expression of the human PPAR γ genes have not yet been disclosed.

III. SUMMARY OF THE INVENTION

The present invention is related to the isolation, cloning and identification of the promoters and other regulatory elements of the PPAR γ gene and the use of PPAR γ gene control regions to screen for agents that modulate PPAR γ gene expression and thence use these modulators as lead compounds to design or search for other drugs to treat disease related to the level of PPAR γ gene expression. The isolated PPAR γ gene control regions have utility in constructing in vitro and in vivo experimental models for studying the modulation of PPAR γ gene expression and assaying for modulators of PPAR γ gene expression. Such experimental models make it possible to screen large collections of natural, semisynthetic, or synthetic compounds for therapeutic agents that affect PPAR γ gene expression.

Thus, in one aspect, the present invention is directed to an isolated, purified, enriched or recombinant nucleic acid containing a control region of a human PPAR γ gene.

By "control region" is meant a nucleic acid sequence capable of, required for,

assisting or impeding initiating, terminating, or otherwise regulating the transcription of a gene, including, but not limited to, promoter, enhancer, silencer and other regulatory elements (*e.g.* those regulating pausing or anti-termination). A positive transcription element increases the transcription of the PPAR γ gene. A negative transcription element decreases the transcription of the PPAR γ gene. A control region also includes nucleic acid sequences that, although insufficient to initiate, terminate, or otherwise regulate the transcription of human PPAR γ gene by themselves, are capable of doing so in combination or coordination with other nucleic acid sequences. A control region can be in nontranscribed regions of a gene, introns or exons. A control region can be in the 5' upstream region or the 3' downstream region to the amino acid coding sequence. A control sequence can be a single regulatory element from a gene. A control region can also have several regulatory elements from a gene linked together. These several regulatory elements can be linked in a way that is substantially the same as in nature or in an artificial way.

A control region in introns and exons may also be involved with regulating the translation of a PPAR γ protein, *e.g.* splicing, processing heteronuclear ribonucleoprotein particles, translation initiation and others described in Oxender, *et al. Proc. Natl. Acad. Sci. USA* 76:5524 (1979) and Yanofsky, *Nature* 289:751-758, (1981).

A control region of this invention is isolated or cloned from the human PPAR γ gene. It is distinguished from control regions disclosed in the prior art in that it contains a regulatory element of novel or unique nucleic acid sequence for the human PPAR γ gene, a known regulatory element set in a novel or unique nucleic acid sequence context for the human PPAR γ gene, or a few known regulatory elements linked in a novel or unique way for the human PPAR γ gene. The human PPAR γ gene control regions include what is in plasmids PPAC8856 and PPAR γ 1 promoter-luc, both of which are deposited at ATCC with accession numbers 97906 and 97862, respectively. The human PPAR γ gene control regions also include what are in plasmids pGL3 γ 1p3000, pGL3 γ 2p1000 and pGL3 γ 3p800. The control region in pGL3 γ 1p3000 starts at the 5' end at nt 2 of SEQ ID NO: 2 and ends at the 3' end, immediately before the reporter gene, at nt 185 of SEQ ID NO: 1. The

control region in pGL3y2p1000 starts at the 5' end at nt 399 of SEQ ID NO: 3 and ends at the 3' end, immediately before the reporter gene, at nt 1438 of SEQ ID NO: 3. The control region in pGL3y3p800 starts at the 5' end at nt 368 of SEQ ID NO: 34 and ends at the 3' end, immediately before the reporter gene, at nt 1218 of SEQ ID NO: 34.

- 5 Preferably, the control region is selected from one of the following regions:
the 1kb fragment 5' upstream of the transcription initiation site of the
human PPAR γ 1 gene, exon A1, intron A1, the 800 nt 5' upstream of the
transcription initiation site of the human PPAR γ 3 gene, exon A2, intron A2,
the 500 nt 5' upstream of the transcription initiation site of the human
10 PPAR γ 2 gene, exon B, and intron B.

A nucleic acid of this invention can be single stranded or double stranded, DNA or RNA, including those containing modified nucleotides known to one skilled in the art. The complementary strand of an identified sequence is contemplated herein.

- 15 In a preferred embodiment, the nucleic acid contains a control region and an amino acid coding region of the human PPAR γ gene, *e.g.*, one or more of exons 1, 2, 3, 4, 5 and 6 of the human PPAR γ gene. In a more preferred embodiment, the nucleic acid contains the entire coding region of human PPAR γ gene.

- 20 In another preferred embodiment, the nucleic acid does not contain one or more of exons 1, 2, 3, 4, 5 and 6 of the human PPAR γ gene. In a more preferred embodiment, the nucleic acid does not contain any one of exons 1, 2, 3, 4, 5 and 6 of the human PPAR γ gene.

In another preferred embodiment, the nucleic acid contains a fragment listed in the following Table III:

Nucleic acid fragment	SEQ ID NO:	Human PPAR γ gene
1 - 125	1	γ 1
1 - 221	1	γ 1
1 - 503	1	γ 1
818 - 1320	3	γ 2
818 - 1442	3	γ 2
1 - 2045	3	γ 2
368 - 1144	34	γ 3
368 - 1218	34	γ 3
1 - 1433	34	γ 3

In another preferred embodiment, the nucleic acid contains a control region cloned in plasmid PPAC8856, which is deposited at ATCC with accession number 97906. In yet another preferred embodiment, the nucleic acid contains a control region cloned in plasmid PPAR γ 1 promoter-luc, which is deposited at ATCC with accession number 97862. In particular, the control region is one of nt -125 to +196 of the human PPAR γ 1 gene, nt -502 to +182 of the human PPAR γ 2 gene, or nt -777 to +74 of the human PPAR γ 3 gene. The “-” and “+” refer to 5’ upstream or 3’ downstream to the transcription initiation sites of human PPAR γ gene.

10 In another preferred embodiment, the control region is a positive transcription element capable of up regulating the transcription of the human PPAR γ 1, γ 2 or γ 3 gene, *e.g.* containing a positive transcription element from nt -125 to +196 of the human PPAR γ 1 gene, nt -502 to +182 of the human PPAR γ 2 gene, or nt -777 to +74 of the human PPAR γ 3 gene.

15 In another preferred embodiment, the control region is a negative transcription element capable of down regulating the transcription of the human PPAR γ 1, γ 2 or γ 3 gene, *e.g.* containing a negative transcription element from nt -125 to +196 of the human

PPAR γ 1 gene, nt -502 to +182 of the human PPAR γ 2 gene, or nt -777 to +74 of the human PPAR γ 3 gene.

In yet another preferred embodiment, the control region contains one or more CACC box, C/EBP binding site, TATA box, SP1 binding site, AP-1 binding site, and
5 ADD-1/SREBP-1 binding site existing in Seq. ID NO: 1, 2, 3 or 34.

The control region may contain at least 100, 60, 30, 12, 8 or 6 contiguous nucleotides from the 5' non-coding sequence (5' UTR) or an intron of the human PPAR γ 1, γ 2 or γ 3 gene.

In other preferred embodiments, the control region is a promoter capable of
10 initiating the transcription of the PPAR γ gene.

By "promoter" is meant a DNA regulatory region capable of binding directly or indirectly to RNA polymerase in a cell and initiating transcription of a downstream (3' direction) coding sequence.

A preferred promoter of this invention contains a sequence in the above Table III.
15 In another preferred embodiment, the promoter contains a sequence selected from the group consisting of the 1kb fragment 5' upstream of the transcription initiation site of the human PPAR γ 1 gene, exon A1, intron A1, the 800 nt 5' upstream of the transcription initiation site of the human PPAR γ 3 gene, exon A2, intron A2, the 500 nt 5' upstream of the transcription initiation site of the human PPAR γ 2 gene, exon B, and intron B. In yet
20 another preferred embodiment, the promoter contains nt -125 to +196 of the human PPAR γ 1 gene, nt -502 to +182 of the human PPAR γ 2 gene, or nt -777 to +74 of the human PPAR γ 3 gene.

A promoter of a DNA construct, including an oligonucleotide sequence according to the present invention, can be linked to a heterologous gene to regulate transcription
25 from the heterologous gene, which includes genes for reporter sequences such as growth hormone, luciferase, green fluorescent proteins, chloramphenicol acetyl transferase, β -galactosidase secreted placental alkaline phosphatase and other secreted enzyme reporters.

By "isolated" in reference to nucleic acid is meant a polymer of 2 (preferably 21,

more preferably 39, most preferably 75) or more nucleotides conjugated to each other, including DNA or RNA that is isolated from a natural source or that is synthesized. The isolated nucleic acid of the present invention is unique in the sense that it is not found in a pure or separated state in nature. Use of the term "isolated" indicates that a naturally occurring sequence has been removed from its normal cellular context. Thus, the sequence may be in a cell-free solution or placed in a different cellular environment or nucleic acid context. The term does not imply that the sequence is the only nucleotide chain present, but does indicate that it is the predominate sequence present (at least 10 - 20% more than any other nucleotide sequence) and is essentially free (about 90 - 95% pure at least) of non-nucleotide material naturally associated with it. The term does not encompass an isolated chromosome containing a PPAR γ gene control region.

By "enriched" in reference to nucleic acid is meant that the specific DNA or RNA sequence constitutes a significantly higher fraction (2 - 5 fold) of the total DNA or RNA present in the cells or solution of interest than in normal or diseased cells or in the cells from which the sequence was taken. This could be caused by a person by preferential reduction in the amount of other DNA or RNA present, or by a preferential increase in the amount of the specific DNA or RNA sequence, or by a combination of the two. However, it should be noted that enriched does not imply that there are no other DNA or RNA sequences present, just that the relative amount of the sequence of interest has been significantly increased in a useful manner and preferably separate from a library of undefined clones. The term "significantly" here is used to indicate that the level of increase is useful to the person making such an increase, and generally means an increase relative to other nucleic acids of about at least 2 fold, more preferably at least 5 to 10 fold or even more. The term also does not imply that there is no DNA or RNA from other sources. The DNA from other sources may, for example, comprise DNA from a yeast or bacterial genome, or a cloning vector such as pUC19. This term distinguishes from naturally occurring events, such as viral infection, or tumor type growths, in which the level of one mRNA may be naturally increased relative to other species of mRNA. That is, the term is meant to cover only those situations in which a person has intervened to elevate the proportion of the desired nucleic acid.

By "purified" in reference to nucleic acid does not require absolute purity (such as a homogeneous preparation); instead, it represents an indication that the sequence is relatively purer than in the natural environment (compared to the natural level this level should be at least 2-5 fold greater, *e.g.*, in terms of mg/ml). Individual clones isolated from a genomic or cDNA library can be purified to electrophoretic homogeneity. The claimed DNA molecules obtained from these clones could be obtained directly from total DNA or from total RNA. The genomic or cDNA clones are not naturally occurring, but rather are preferably obtained via manipulation of a partially purified naturally occurring substance.

By "recombinant" in reference to nucleic acid is meant the nucleic acid is produced by recombinant DNA techniques such that it is distinct from a naturally occurring nucleic acid.

By "enhancer" is meant a DNA regulatory region that enhances transcription. An enhancer is usually, but not always, located outside the proximal promoter region and may be located several kilobases or more from the transcription start site, even 3' to the coding sequence or within the introns of the gene. Promoters and enhancers may alone or in combination confer tissue specific expression.

By "silencer" is meant a control region of DNA, which, when present in the natural context of the PPAR γ gene, causes a suppression of the transcription from that promoter either from its own actions as a discreet DNA segment or through the actions of trans-acting factors binding to said elements and effecting a negative control on the expression of the gene. This element may play a role in the restricted cell type expression pattern seen for the PPAR γ gene, for example expression may be permissive in adipocytes where the silencer may be inactive, but restricted in other cell types in which the silencer is active. This element may or may not work in isolation or in a heterologous promoter construct.

By "comprising" is meant including, but not limited to, whatever follows the word "comprising". Thus, use of the term "comprising" indicates that the listed elements are required or mandatory, but that other elements are optional and may or may not be present.

By "consisting of" is meant including, and limited to, whatever follows the phrase
5 "consisting of". Thus, the phrase "consisting of" indicates that the listed elements are required or mandatory, and that no other elements may be present. By "consisting essentially of" is meant including any elements listed after the phrase, and limited to other elements that do not interfere with or contribute to the activity or action specified in the disclosure for the listed elements. Thus, the phrase "consisting essentially of" indicates
10 that the listed elements are required or mandatory, but that other elements are optional and may or may not be present depending upon whether or not they affect the activity or action of the listed elements.

The specific control regions identified above can be modified by terminal deletions without abolishing their regulatory functions using methods known to those skilled in the art, including, but not limited to, those disclosed in U.S. Patent 5698389, incorporated by
15 reference herein. Therefore, this invention also encompasses terminal deletion mutants of the above-identified human PPAR γ control regions.

In a second aspect, the invention features a recombinant nucleic acid comprising a control region of the human PPAR γ gene as described above and a reporter gene sequence
20 such as luciferase. The recombinant nucleic acid is preferably inserted in a vector (virus vector or plasmid vector). In addition, the recombinant nucleic acid is preferably transfected into a cell or an organism. The control region and the reporter sequence are operably linked so that the control region, such as a promoter, is effective to initiate, terminate or regulate the expression of the reporter sequence. The control region may
25 contain one of human PPAR γ 1 promoter, human PPAR γ 2 promoter and human PPAR γ 3 promoter. Alternatively, the control region may contain two or three of the promoters in combination. The recombinant nucleic acid may further comprise a transcriptional termination region functional in a cell.

In a preferred embodiment, the promoter contains the region from about -3kb to about +110 bp relative to the transcription initiation site of human PPAR γ 1 gene, from about -1kb to about +122bp relative to the transcription initiation site of human PPAR γ 2 gene, or from about -800bp to about +1bp relative to the transcription initiation site of human PPAR γ 3 gene. Exemplary recombinant nucleic acids are pGL3- γ 1p3000, pGL3- γ 2p1000, and pGL3- γ 3p800.

The PPAR γ gene control regions and the 5' untranslated region (5'UTR) described herein are useful for designing and preparing antisense molecules that interfere or inhibit RNA processing or translation of the PPAR γ gene. The PPAR γ gene control regions and the 5' untranslated region (5'UTR) described herein are also useful for designing and preparing ribozymes that cleave transcripts from the genomic PPAR γ sequence, interfere or inhibit RNA processing or translation of the PPAR γ gene. Such antisense molecules and ribozymes down regulate the expression of the PPAR γ gene.

Therefore, in a third aspect, this invention features antisense molecules and ribozymes capable of down regulating the expression of the human PPAR γ gene. The antisense nucleic acids of this invention are DNA or RNA molecules that are complementary to a PPAR γ gene control region or a 5' untranslated region of PPAR γ and hybridize to PPAR γ transcripts in the cell to block RNA processing or translation. Antisense methods have been used to inhibit the expression of many genes in vitro (Marcus-Sekura, *Anal. Biochem.* 172:289-295, 1988; Hambor *et al.*, *J. Exp. Med.*, 168:1237-1245, 1988). Ribozymes of this invention are RNA molecules possessing the ability to specifically cleave PPAR γ transcripts containing a PPAR γ gene control region or a 5' untranslated region of PPAR γ in the cell (Cech, *J. Am. Med. Assoc.*, 260:3030-3034 (1988). Ribozymes capable of modulating the expression of a PPAR γ gene can be designed and synthesized with methods known to one skilled in the art such as those disclosed in Stinchcomb, *et al.* "Method and Reagent for Inhibiting the Expression of Disease Related Genes," WO 95/23225.

In a fourth aspect, the present invention features a method for identifying agents which modulate or regulate the transcription of a PPAR γ gene. Such agents are identified based on their ability to modulate the expression of a chimeric gene as described above wherein a heterologous coding sequence is regulated by a PPAR γ gene control region

5 taught by the present invention. Agents identified in this manner are useful as lead compounds to design or search for other drugs to treat disease related to the level of PPAR γ gene expression. This method includes the following steps: (a) providing a recombinant nucleic acid as described above wherein a heterologous coding sequence is regulated by a human PPAR γ gene control, wherein the control region is operably or

10 transcriptionally linked to the reporter sequence to initiate, terminate or regulate the transcription of reporter, (b) contacting a candidate agent with a system containing the recombinant nucleic acid, and (c) assaying for a measurable difference in the level of transcription of the reporter sequence as an indicant of the candidate agent's activity. An agent that increases the level of transcription of the nucleic acid sequence is an up

15 regulator. An agent that decreases the level of transcription of the nucleic acid sequence is a down regulator. The system can be a cell, an animal such as a mammal, or an in vitro transcription system. The preferred cells are eukaryotic cells, including yeast cells and mammalian cells.

In a preferred embodiment, the nucleic acid is introduced into a host cell or an

20 organism by transfection, adenovirus infection or other methods of gene transfer and the system includes the cell or the organism. In an even further preferred embodiment, a transgenic animal system is used in the assay.

In another preferred embodiment, the system further includes a transcriptional protein. By "transcriptional protein" is meant a cytoplasmic or nuclear protein that, when

25 activated, binds a promoter, enhancer or silencer either directly, or indirectly through a complex of proteins to modulate the transcription activity of the promoter. The transcriptional protein may either be endogenous to the cell or expressed from a recombinant nucleic acid transfected into the cell. Examples of transcriptional proteins include, but are not limited to, C/EBP β protein and other proteins that bind to a C/EBP site

30 or Sp1 site, and intracellular receptors. In a preferred embodiment, the transcriptional

protein is ADD1/SREBP1. By "intracellular receptor" is meant an intracellular transcription factor whose activity is regulated by binding of small molecules, including, but not limited to, estrogen receptor (ER), retinoid acid receptors (RAR), retinoid X receptors (RXR), glucocorticoid receptors (GR), progesterone receptors (PR), androgen
5 receptors (AR), thyroid hormone receptors (TR), and vitamin D receptors. The intracellular receptor may either be endogenous to the cell or expressed from a recombinant nucleic acid transfected into the cell. A preferred intracellular receptor is an RXR such as RXR α .

In another preferred embodiment, the basal level of the mammalian PPAR γ gene
10 expression may be raised up before adding a candidate down regulator to the screening assay.

In a preferred embodiment, the assay is conducted in a mammalian adipocyte cell such as a primary adipocyte cell or an immortalized adipocyte cell. A rat, mouse or a human primary adipocyte cell is used. Mammalian preadipocytes may be used for the
15 assay as well. Exemplary cells include 3T3-F422A, Ob1771, Ob17, 3T3-L1 and rat primary adipocyte. Any other cells in which the control region is capable of initiating, terminating or regulating the transcription of the reporter sequence may be used.

In another preferred embodiment, the sequence of the control region is used to guide the selection of potential modulators for screening. For example, if a glucocorticoid
20 response element (GRE) is present in the control region, compounds known to act through these elements will be selected for screening. Other control elements useful in this way include, but are not limited to, peroxisome proliferator response elements (PPRE), thyroid hormone response elements (TRE), retinoic acid response elements (RARE), retinoid X response elements (RXRE), estrogen response elements (ERE), progesterone response
25 elements (PRE), androgen response elements (ARE), insulin receptor response elements, other transcription regulatory binding sites such as the helix-loop-helix family members including sterol regulatory element binding protein family (SREBP) or its adipocyte expressed homologue ADD-1, CAAT/enhancer binding protein (C/EBP), AP-1, AP-2, SP-1, NF κ B, Oct-1, serum response elements, cAMP response elements, and growth hormone
30 (GH) response elements.

In a preferred embodiment, the candidate agent is selected from the group consisting of estrogen receptor, retinoid acid receptors, retinoid X receptors, glucocorticoid receptors, progesterone receptors, androgen receptors, thyroid hormone receptors, and vitamin D receptors.

5 Peptide or small molecule combinatorial libraries can be used to screen for modulators of PPAR γ gene expression (Bunin, B.A.N. Ellman, *J. A., J. Am. Chem. Soc.* 114:10997-10998 (1992) and references contained therein).

The above described assays can be modified to allow assaying for agents that modulates the interaction of a transcriptional protein (*e.g.*, ADD1/SREBP1) with a control
10 region of the human PPAR γ gene by including the regulatory protein in the assay. The activity of the agents is measured by the expression level of the reporter gene: In a preferred embodiment, the regulatory protein is expressed from a recombinant vector transfected into the assay system (*e.g.*, a cell). Alternatively, the interaction or binding of the transcriptional protein control region of the human PPAR γ gene can be measured by
15 other techniques known to those skilled in the art, including, but not limited to, mobility shift assay, and co-transfection assay.

The activities of a candidate compound on the control regions of human PPAR γ 1, γ 2, and γ 3 can be compared to determine whether it has different effects on different human PPAR γ promoters. Thus, this invention allows one to identify a modulator that is
20 specific for one or more of human PPAR γ 1, γ 2, and γ 3 genes. In addition, the activities of a candidate compound on a control region of human PPAR γ gene in different cells and tissues can be compared to determine the tissue specific function of the compound. In that regard, this invention allows one to identify a modulator that has tissue specific activity on one or more of human PPAR γ 1, γ 2, and γ 3 genes.

In a fifth aspect, the present invention features a method of identifying agents which modulate or regulate the transcription of a PPAR γ gene by testing their ability to bind to a control region of the human PPAR γ gene. An example is provided in the detailed description of the invention where a modulator of PPAR γ gene, ADD-1/SREBP-1, was found to bind to the PPAR γ 3-E-box.

While steroids and steroid analogues may exemplify agents identified by the present invention, Applicant is particularly interested in the identification of agents of low molecular weight (less than 10,000 Daltons, preferably less than 5,000, and most preferably less than 1,000) which can be readily formulated as useful therapeutic agents.

Such agents can then be screened to ensure that they are specific to tissues with pathological conditions related to PPAR γ gene expression with little or no effect on healthy tissues such that the agents can be used in a therapeutic or prophylactic manner. If such agents have some effect on healthy tissues they may still be useful in therapeutic treatment, particularly in those diseases which are life threatening.

Once isolated, a candidate agent can be put in pharmaceutically acceptable formulations, such as those described in Remington's Pharmaceutical Sciences, 18th ed., Mack Publishing Co., Easton, PA (1990), incorporated by reference herein, and used for specific treatment of diseases and pathological conditions with little or no effect on healthy tissues.

In a sixth aspect, this invention features a pharmaceutical composition capable of modulating the transcription activity of a human PPAR γ gene control region, i.e. containing a pharmaceutically effective amount of a modulator (*e.g.* up regulator or down regulator) of the mammalian PPAR γ gene control region. In a preferred embodiment, the composition is held within a container which includes a label stating to the effect that the composition is approved by the FDA in the United States (or other equivalent labels in other countries) for treating a disease or condition selected from the group consisting of obesity, anorexia, cachexia, lipodystrophy, lipomas, liposarcomas, abnormalities of adipose tissue associated with anti-HIV treatment, insulin resistance, diabetes mellitus (NIDDM), polycystic ovary syndrome, lipodystrophy, diseases of the GI tract, inflammatory bowel disease, Crohn's disease, ulcerative colitis, bowel cancer, irritable

bowel syndrome, ulcerations of the GI tract, hyper- and dyslipidemia, hypertriglyceridemia, hypo-alpha lipoproteinemia, atherosclerosis, cardiovascular diseases, acute inflammation, septic shock, infection, chronic inflammation, inflammatory bowel disease, rheumatoid arthritis, allergic conditions, urticaria, eczema, asthma, immulogic disorders, graft versus-host disease, parasitic infections, bacterial infections, viral infections, breast cancer, prostate cancer, colon cancer, osteoporosis, bone loss, ARDS, and RDS.. Such a container will provide therapeutically effective amount of the active ingredient to be administered to a host.

In a seventh aspect, this invention features a method for modulating the expression level of human PPAR γ gene by administering to a host a composition including an effective amount of a modulator (*e.g.* up regulator or down regulator) of the control region

In a preferred embodiment, the method further includes step of measuring the transcriptional activity of the control region.

In further preferred embodiments, the composition includes an up regulator.

In another further preferred embodiments, the composition includes a down regulator.

In an eighth aspect, this invention relates to a method of diagnosing abnormal PPAR γ expression in a host by detecting the expression level of human PPAR γ 1, γ 2, or γ 3 in one or more tissue samples from the host. In a preferred embodiment, the expression levels of human PPAR γ 1, γ 2, and γ 3 are detected and compared to that of healthy subjects.

Applicant has obtained intron sequences surrounding exons 1, 2, 3, 4, 5 and 6 (see SEQ ID NOs: 35, 36, 37, 38, 39 and 40). In that regard, this invention features oligonucleotide probes, methods and compositions for diagnosing genomic mutations in exon 1, 2, 3, 4, 5 or 6 of human PPAR γ gene. Genomic mutations in one or more exons can be detected by oligonucleotide primer directed amplification and sequencing. For example, oligonucleotides of about 10 to about 100 bps can be designed to bind to the intron sequences immediately surrounding an exon for amplifying and/or sequencing the exon of genomic DNA in a cell sample collected from a host. Techniques known to those skilled in the art for amplifying and detecting nucleic acid targets can be applied for this aspect of the invention, including, but not limited to, WO 91/01384, EPC publication 0

569 237 A2, U.S. Patent 5683880, incorporated by reference herein in their entirety.

Other features and advantages of the invention will be apparent from the detailed description of the invention below and from the list of enumerated embodiments that follows.

5

IV. BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 shows the transcription initiation sites of the human PPAR γ 1 (SEQ ID NO: 31) and γ 2 (SEQ ID NO: 32) in panels A and B, respectively. Transcription initiation sites as determined by primer extension are indicated by arrows. Transcription initiation sites as determined by 5'-RACE are indicated by asterisks. The sequence corresponding to the 5'-UTR is shown in panel A.

Figure 2 is a schematic comparison of the gene organization of the mouse and human PPAR γ genes. The genes are shown in 5' to 3' orientation and are drawn to scale. Restriction sites for BamHI are indicated by a "B." The location of the ATG start-codon is indicated. The asterisk indicates the different ATG used in mPPAR γ 1. Exons are denoted by gray or black rectangles and introns by solid lines.

Figure 3 is a schematic diagram showing the organization of post-transcription processed human PPAR γ 1, 2 and 3 mRNAs including the 5' untranslated terminal region. A1, A2, B and 1-6 denote exons.

Figure 4 shows sequences of the human PPAR γ 3 promoter, exon A2 and intron A2 (SEQ ID NO: 34). Exon sequence is shown in capitalized letters. A* denotes the transcription initiation site. The ADD1/SREBP1 site, C/EBP site and TATA box are indicated in bold. The oligonucleotide LF-60 used for primer extension is indicated by an arrow.

Figure 5 shows sequences of the human PPAR γ 1 proximal promoter, exon A1 and intron A1 (SEQ ID NO: 1). Exon sequence is shown in capitalized letters. G* denotes the transcription initiation site. The CACC box and Sp1 site are indicated in bold.

Figure 6 shows the upstream sequence of the human PPAR γ 1 promoter 5' to the sequence shown in Figure 5 (SEQ ID NO: 2).

Figure 7 shows sequences of the human PPAR γ 2 promoter, exon B and intron B

(SEQ ID NO: 3). Exon sequence is shown in capitalized letters. T* denotes the transcription initiation site. The TATA like box, C/EBP site, AP-1 site and translation initiation site are indicated in bold.

5 **V. DETAILED DESCRIPTION OF THE INVENTION**

Two important findings recently underlined the importance of the PPAR γ transcription factor. First, PPAR γ has been identified as one of the key factors controlling adipocyte differentiation and function in rodent systems (6, 7). Second, the recent identification of prostaglandin J2 derivatives and antidiabetic thiazolidinediones as natural
10 and synthetic PPAR γ ligands, respectively (28, 29, 46-48). Thiazolidinediones are a new group of anti-diabetic drugs which improve insulin-resistance (for review, see Refs. 49 and 50). The identification of thiazolidinediones as PPAR γ ligands together with the central role that adipose tissue plays in the pathogenesis of important metabolic disorders, such as obesity and non-insulin-dependent diabetes mellitus (NIDDM), have generated a major
15 interest to determine the role of this PPAR subtype in normal and abnormal adipocyte function in humans.

To identify the molecular circuitry underlying tissue-specific expression of PPAR, we cloned and performed a characterization of the human PPAR γ promoters. As shown, 3000 bp of the PPAR γ 1 and 1000 bp of the PPAR γ 2 promoter account for substantial
20 levels of basal promoter activity.

In addition to PPAR γ , the basic helix-loop-helix leucine zipper factor ADD-1/SREBP1 and transcription factors of the C/EBP family also play a role in determining adipocyte differentiation. As in the mouse PPAR γ 2 promoter (45), a potential consensus

C/EBP response element is identified in the human PPAR γ 2 promoter by homology searches. This observation fits well with the previous observation that forced expression of C/EBP α could induce PPAR γ expression (11, 12).

5 **A. Cloning of the human PPAR γ cDNA**

A cDNA probe containing a 200-bp (KpnI-BglII) fragment encoding the DNA binding domain of the mouse PPAR γ (44) was used to screen a human adipose tissue cDNA library. Several independent human PPAR γ cDNA clones, representing both the PPAR γ 1 and PPAR γ 2 subtypes, were isolated and sequenced. The human PPAR γ protein
10 shows a 99% similarity and a 95% identity at the amino acid level with mouse PPAR γ (45). Relative to the mouse, hamster, and Xenopus PPAR γ (6, 39, and 51), the human protein contains two additional amino acids. This is in agreement with the previous reports on the human PPAR γ cDNA (34, 35, and 52).

15 **B. Locating Promoters of the Human PPAR γ Genes**

Two approaches were undertaken to identify the 5'-end of the cDNA. First, primer extension experiments were performed, utilizing different human adipose tissue RNA samples. The result from primer extension was independently confirmed by 5'-RACE.

Several primer extension products were seen for the PPAR γ 1 mRNA. The relative
20 positions of the transcription initiation sites as determined by the 5'-RACE were in agreement with the results for primer extension.

One major extension product of 62 bp was observed consistently with the primer LF-35 for PPAR γ 2. A second extension product of 96 bp was found using the same. The result of 5'-RACE was consistent with the primer extension. The transcription initiation
25 sites identified correlated well with the transcription initiation sites observed for the mouse PPAR γ 2 mRNA (45). A striking feature of the human PPAR γ 2 5'-UTR is its high degree of sequence conservation with the mouse 5'-UTR.

We cloned the regions 5' to the transcription initiation sites of PPAR γ 1 and γ 2 and sequenced the proximal promoters.

No canonical TATA box was found in the PPAR γ 1 promoter region close to the transcription initiation site (Figure 1). The sequence immediately upstream of the transcription initiation site is extremely GC-rich, including several consensus Sp1 binding sites. A CCAAC box was found in the proximal promoter.

The PPAR γ 2 promoter contains a TATA-like element at position -68, relative to the transcription initiation site. Furthermore, sequence analysis identified a potential CAAT-like consensus C/EBP protein binding site at -56 (CCAATT) and a perfect AP-1 site at +10 (TGACTCA) (Figs. 1 and 3).

A more detailed analysis of the 5' upstream sequence of exon A2 (Figure 2) indicated the presence of a TATA and CCAAT box. This suggests the presence of a third promoter in the PPAR γ gene and an alternative PPAR γ mRNA containing only the exon A2 in its 5' UTR.

In order to assess this possibility, an RNase protection assay was performed using a radiolabelled probe containing both the A1 and A2 untranslated exons plus a sequence common for all PPAR γ mRNAs, i.e., exon 1. In the presence of a PPAR γ mRNA species containing exclusively exon A2, this probe yielded a protected fragment that is 42 bp shorter than the fragment present in PPAR γ 1, which contains both exons A1 and A2.

In addition, RNase protection assays of RNA from colon and adipose tissues - two tissues known to express high levels of PPAR γ - showed an additional RNA species, which is different from PPAR γ 1 and 2. The size of this new mRNA species corresponds to an RNA containing only exon A2.

We performed primer extension experiments on human adipose tissue RNA to identify the 5' end of this novel PPAR γ cDNA. One major primer extension product of 37 bp was observed with the primer LF-60. The length of the extended product indicates that this new mRNA begins at the initiation of the exon A2. In the same primer extension assay, we could not observe any band corresponding to the PPAR γ 1 transcription initiation site because the length of the extended product corresponding to the PPAR γ 1 mRNA is

longer than 180 bp, which makes it very difficult to detect using this technique. These data unequivocally demonstrate the presence of an additional PPAR γ transcription initiation site giving rise to a new PPAR γ mRNA which we designated as PPAR γ 3. The PPAR γ 3 mRNA will, however, be translated into a protein that is indistinguishable from PPAR γ 1 because there is no translation initiation site in exon A2.

Accordingly, the locations of the three promoters for the human PPAR γ gene are shown in Figure 2.

We sequenced the region 5' to the transcription initiation site of the PPAR γ 3 mRNA, which corresponds to the proximal PPAR γ 3 promoter (Figure 4). Several consensus sequence elements were identified. A TATA-like element was found at -34 relative to the transcription initiation site. Sequence analysis furthermore identified a potential CAAT-like consensus C/EBP binding site at -118 as well as a potential E-box binding site for the transcription factor ADD-1/SREBP-1 at the position -342 (Figure 4).

To clone the human PPAR γ gene and to determine its promoter sequence, we screened a PAC human genomic library derived from human foreskin fibroblasts. Three positive clones (P-8854, P-8855, and P-8856), each spanning >100 kb of genomic sequence, were isolated. All three clones were next shown to hybridize with the oligos LF-14 (corresponding to exon B) and LF-36 (exon 6), which indicates that they span most of the PPAR γ coding region. More importantly, clone P-8856 also hybridized to oligo LF-2 and, hence, contains the transcription initiation site for PPAR γ 1 and 2. This clone was further characterized by Southern blotting and partial sequence analysis, which allowed the construction of a physical map of the human PPAR γ locus (Figure 2).

The human PPAR γ gene has nine exons and extends over more than 100 kilobases of genomic DNA. Alternate transcription start sites and alternate splicing generate the PPAR γ 1 and PPAR γ 2 mRNAs, which differ at their 5'-ends. PPAR γ 1 is encoded by eight exons, and PPAR γ 2 is encoded by seven exons. The 5'-untranslated sequence of PPAR γ 1 is comprised of exons A1 and A2. The 5'-untranslated sequence of PPAR γ 2 plus the additional 28 PPAR γ 2-specific N-terminal amino acids are encoded by exon B, which is located between exons A2 and A1. The remaining six exons, termed 1 to 6, are common to

the PPAR γ 1 and γ 2. A third PPAR γ mRNA, PPAR γ 3, is transcribed from an independent promoter localized 5' of exon A2.

The length of the introns was determined by long-range PCR (CLONTECH Tth polymerase mix) using the oligonucleotide pairs LF-3/LF-18, LF-20/LF-21, LF-22/LF-23, LF-24/LF-25, LF-26/LF-27, and LF-28/LF-29 and the PAC clone P-8856 as a template. The intron-exon boundaries were sequenced using genomic DNA as template. The 5' donor and 3' acceptor splice sites were found to be conforming to the consensus splice donor and acceptor sequences (Table II). The DNA binding domain of the receptors is encoded by exons 2 and 3, each encoding a separate zinc finger. The entire ligand-binding domain is encoded by exons 5 and 6, which are separated by 16.3 kb of intron sequence.

C. Tissue-Specific Expression of human PPAR γ 1, 2 and 3

We employed two RNase protection assays to study the relative expression of the three PPAR γ subtypes in different tissues (see the methods section and Table I for the description of the probes). The first RNase protection assay was designed to determine the amount of PPAR γ 2 mRNA relative to PPAR γ 1 and PPAR γ 3 mRNAs, whereas the second RNase protection assay was designed to determine the amount of PPAR γ 3 relative to PPAR γ 1 and PPAR γ 2 mRNA.

Human PPAR γ 3 mRNA is expressed in adipose tissue, CaCo2 cells from the intestine and macrophages. With the exception of human white adipose tissue, none of the tissues or cell-lines analyzed contained substantial amounts of PPAR γ 2 mRNA. In contrast to the tissue restricted expression of the PPAR γ 2 and 3 mRNAs, PPAR γ 1 mRNA is more widely expressed and is detected in adipose tissue, human hepatocytes, and the cell-lines Hep G2 (liver), CaCo2, HeLa (uterus), and THP1 (monocyte/macrophage). The expression of PPAR γ 3 mRNA is induced upon differentiation of the CaCo2 cell line.

To evaluate the tissue specificity of these promoters, DNA fragment extending from about -3 kb to +110 bp relative to the transcription initiation site of PPAR γ 1 was inserted into the pGL3-basic luciferase vector (Promega) to generate the construct pGL3- γ 1p3000. DNA fragment extending from about -1 kb to +122 bp relative to the transcription initiation site of PPAR γ 2 was inserted into the pGL3-basic luciferase vector (Promega) to generate the construct pGL3- γ 2p1000. These vectors were then transfected into mouse 3T3-L1 and Hep G2 cells. Transfection efficiency of the various cell lines was monitored by evaluation of the activity of control vectors.

Relative to the promoterless parent vector, the human PPAR γ 1 promoter fragment stimulated luciferase expression up to 3.5-fold in 3T3-L1 cells, maintained under non-differentiating conditions. In Hep G2 cells, luciferase expression was nine-fold higher with the pGL3- γ 1p3000 vector relative to the pGL3-basic vector. Similar results were obtained with COS cells. The expression of the pGL3- γ 2p1000 construct containing the PPAR γ 2 promoter was not different from the pGL3-basic promoterless vector in Hep G2 cells. In undifferentiated 3T3-L1 cells, the PPAR γ 2 promoter induced luciferase expression 2-fold relative to the promoterless control.

To evaluate the activity and tissue specificity of the PPAR γ 3 promoter, we cloned an 800 bp fragment located immediately upstream of the transcription initiation site of PPAR γ 3 into the luciferase reporter vector pGL3 basic. The resulting plasmid pGL3- γ 3p800 was transfected into the mouse 3T3-L1 and human Hep G2 cell lines. Transfection efficiency was monitored by evaluation of the activity of a β -galactosidase control vector. Relative to the promoterless parent vector, the PPAR γ 3 promoter stimulated the luciferase expression more than two-fold in Hep G2 cells and in undifferentiated 3T3-L1 cells. The activity of the PPAR γ 3 promoter was in the same range as the activity observed for the PPAR γ 1 and γ 2 promoter in these cells. The relative weak stimulation of luciferase gene expression in undifferentiated 3T3-L1 and Hep G2 cells is in agreement with the low level of expression of PPAR γ in these cells.

To analyze the expression pattern of the PPAR γ isoforms, we developed a sensitive RT-competitive PCR assay in which relative amounts of PPAR γ 1 and γ 2 mRNA could be measured in minute quantities of RNA (0.1 μ g total RNA). This method relies on the co-amplification in the same tube of known amounts of competitor DNA with PPAR γ cDNA, obtained after reverse transcription from total tissue RNA. The competitor and the target use the same fluorescently labeled PCR primers but yield amplicons of different sizes, allowing their separation and quantification on an automated sequencing gel at the end of the reaction.

All tissue preparations were carefully dissected, and the RNA was shown to be free of contamination by adipose tissue as evidenced by the absence of human leptin mRNA by RT-competitive PCR assay (38).

PPAR γ 1 mRNA was the predominant PPAR γ isoform in all human tissues analyzed. PPAR γ 2 was detected in both liver and adipose tissue where it accounted for 15% of all PPAR γ mRNA. In addition to the high level of expression of PPAR γ mRNA expected in adipose tissue, we found a very high level of PPAR γ 1 in large intestine. In contrast to adipose tissue, large intestine contained no PPAR γ 2 mRNA. Kidney, liver, and small intestine contained intermediate levels of PPAR γ mRNA, whereas PPAR γ mRNA was barely detectable in skeletal muscle. PPAR γ 3 mRNA, which gives rise to a protein identical to PPAR γ 1, is exclusively expressed in adipose tissue and the large intestine.

Next, the expression of the human PPAR γ protein was analyzed in human adipose tissue. A PPAR γ specific antibody, raised against a peptide corresponding to amino acids 20-104 of mPPAR γ , was used. This antibody is highly specific for PPAR γ and does not cross-react with PPAR α and β in Western blot experiments. Using this antibody in a Western blot of protein extracts from human adipose tissue, we detected a band (potentially representing a doublet) with an approximate molecular mass of 60 kDa, consistent with the predicted mass of PPAR γ 1 and 2 and with the protein product generated by in vitro transcription/translation in the presence of [35S]methionine.

Our results in humans as well as the data by Xue *et al.* (53) in rodent adipocytes show consistently lower levels of PPAR γ 2 mRNA and protein relative to the PPAR γ 1 subtype. These observations are in line with the previous observations that the N-terminal domain of PPAR γ was dispensable, both regarding transcriptional activation and capacity to induce adipocyte differentiation in vitro (7). However, the N-terminal domain is highly conserved between different species, suggesting it might have an important function in vivo.

That PPAR γ expression is much more widespread than previously realized implies that PPAR γ controls gene expression in several tissues in addition to adipose tissue. For example, PPAR γ is expressed in the macrophage and foam cells (Ricote M, *et al.*, *Proc Natl Acad Sci USA* 95(13): 7614-7619 (1988)). Especially striking is the high level of PPAR γ expression in the human large intestine. These results are consistent with the reported high level expression of PPAR γ in colonic mucosa in mouse (54).

PPAR γ is expressed in a subset of macrophages and negatively regulates the expression of several pro-inflammatory genes in response to its ligands. We recently discovered the presence of PPAR γ in human macrophages foam cells of human atherosclerotic lesions. In these cells, PPAR γ is present in a pattern correlated with that of oxidation-specific epitopes. Oxidized low-density lipoprotein (LDL) and macrophage colony stimulating factor (MCSF) are known to be present in atherosclerotic lesions. In addition, oxidized LDL and MCSF stimulate PPAR γ expression in primary macrophages and monocytic cell lines. Furthermore, phorbol esters induced PPAR γ expression. Inhibition of PKC blocked induction of PPAR γ by phorbol esters but not by oxidized LDL, suggesting that more than one pathway regulate PPAR γ expression in macrophages.

Fatty acids, which are potential PPAR activators, have been shown to play an important role in modulating the function of the large intestine. For instance, diets enriched in saturated lipids have been shown to predispose the development of colon cancer (55). Furthermore, it has been shown that diets enriched in omega-3 fatty acids, which are powerful PPAR activators, have a beneficial response on inflammatory diseases of the gastrointestinal tract such as colitis ulcerosa and Crohn's disease (56, 57). The high

level expression of PPAR γ suggest that it plays an important role in normal and abnormal colonic function.

The low levels of PPAR γ expression in skeletal muscle cells suggest that PPAR γ agonists such as TZD's reduce insulin resistance primarily through adipose tissues.

5 Muscle is responsible for clearance of the majority of glucose in the body and abnormal muscle glucose uptake is one of the prime features of insulin resistance and NIDDM. The low levels of PPAR γ in muscle argue, therefore, that the beneficial effects of thiazolidinedione antidiabetic agents are not likely to be due to a direct effect of these agents on PPAR γ present in the muscle. In fact, even though the liver has considerably
10 higher levels of PPAR γ relative to muscle, thiazolidinediones do not seem to affect PPAR responsive genes in liver tissue at the concentrations commonly used to lower glucose levels (23). This observation together with the observed tissue distribution of PPAR γ suggests that the glucose lowering effects of the thiazolidinedione PPAR γ ligands are primarily a result of their activity on adipose tissue, which then, via a secreted signal,
15 influences muscle glucose uptake.

D. PPAR γ 2 Binds and Transactivates through a PPRE (Assay for PPAR γ Agonists and Antagonists)

To analyze whether PPAR γ could bind to a PPRE, classically composed of direct
20 repeats spaced by one intervening nucleotide (DR-1), EMSA was performed using in vitro transcribed/translated PPAR γ 2 protein. An oligonucleotide containing a high affinity PPRE, previously identified in the apoA-II promoter J site, was used in EMSA (29). This oligonucleotide was capable of binding both human and hamster PPAR γ /mRXR α heterodimers in EMSA. Homodimers of either hPPAR γ or mRXR α , however, were
25 incapable of binding to this oligonucleotide. When increasing concentrations of unlabeled apoA-II J site were added as competitor, binding of the hPPAR γ /mRXR α heterodimer to the labeled PPRE was almost completely inhibited. In addition, oligonucleotides corresponding to the PPRE elements of the ACO or LPL genes competed, albeit less efficiently.

We next verified that the human PPAR γ 2 cDNA was capable of activating gene transcription through a PPRE. Therefore, 3T3-L1 preadipocytes were cotransfected with the PPAR γ 2 expression vector pSG5hPPAR γ 2 and a PPRE-driven luciferase reporter gene. The luciferase gene was under the control of a multimerized ACO-PPRE site and the TK promoter. hPPAR γ 2 was capable of activating this PPRE-based reporter 2-fold, an effect which was substantially enhanced when hPPAR γ 2 was cotransfected together with RXR α . Upon the addition of the PPAR γ ligand BRL-14653, luciferase expression was increased 6-fold when the transfection was done with hPPAR γ 2 alone or at least 10-fold when the cells were co-transfected with both hPPAR γ 2 and mRXR α . Similar results were obtained when prostaglandin J2 was used as a PPAR γ ligand. The above-described cell assay can be used to screen for other PPAR γ 2 protein agonists and antagonists. It can also be used to screen for agonists and antagonists of PPAR γ 1 protein by substituting hPPAR γ 2 with hPPAR γ 1.

E. Utility of the Cloned PPAR γ gene control regions

The cloned control regions of the human PPAR γ gene provide a powerful tool for dissecting the role of the PPAR γ gene product in a variety of diseases and disorders. These cloned control regions also provide novel tools for discovering pharmacological modulators of PPAR γ gene expression. In addition, the availability of the structure of the human PPAR γ gene allows for genetic studies of PPAR γ mutations in humans, evaluating its role in disorders such as insulin resistance, NIDDM, and diseases characterized by altered adipose tissue function such as obesity or lipodystrophic syndromes.

1. Assay systems using cells

The host cells used in the screening assay herein preferably are mammalian cells, and more preferably are human cell lines.

5 The host cells may be used to observe the regulation of endogenous PPAR γ gene expression. These cells, whether derived from rodent, human or other mammalian species, can be used to monitor the expression of a reporter gene driven by human PPAR γ gene control elements or regions.

Chimeric reporter genes containing the control regions of the PPAR γ gene operatively linked to a coding sequence for a reporter may be introduced into a host cell
10 according to standard techniques, such as via electroporation technology (Quon, M.J. *et al. Biochem. Biophys. Res. Comm.* 194: 338-346, (1993)).

Cell systems other than mammalian may also be used in the screening assays, such as *Drosophila* (SL-2, Kc or others) and yeast strains (permeabilized or not) such as *S. cerevisiae* or *S. pombe*, provided that such cells are modified to contain a chimeric reporter
15 gene whose expression is regulated by control regions of the PPAR γ gene.

a. Reporter sequences

Generally, reporter genes encode a polypeptide not otherwise produced by the host cell which is detectable by in situ analysis of the cell culture, *e.g.*, by the direct
20 fluorometric, radioisotopic or spectrophotometric analysis of the cell culture without the need to remove the cells for signal analysis from the culture chamber in which they are contained. Preferably the gene encodes an enzyme which produces colorimetric or fluorometric changes in the host cell which is detectable by in situ analysis and which is a quantitative or semi-quantitative function of transcriptional activation. Exemplary
25 enzymes include luciferase, green fluorescent proteins, chloramphenicol acetyl transferase, β -galactosidase, β -lactamase, secreted placental alkaline phosphatase, human growth hormone, esterases, phosphatases, proteases (tissue plasminogen activator or urokinase) and other secreted enzyme reporters and other enzymes whose function can be detected by appropriate chromogenic or fluorogenic substrates known to those skilled in the art.

30 A preferred example is *E. coli* β -galactosidase. This enzyme produces a color

change upon cleavage of the indigogenic substrate indolyl-B-D-galactoside by cells bearing β -galactosidase (see, *e.g.*, Goring *et al.*, *Science* 235:456-458 (1987) and Price *et al.*, *Proc. Natl. Acad. Sci. USA* 84:156-160 (1987)). This enzyme facilitates automatic plate reader analysis of PPAR γ control region mediated expression directly in microtiter wells containing transformants treated with candidate activators. Also, because the endogenous β -galactosidase activity in mammalian cells ordinarily is quite low, the analytic screening system using β -galactosidase is not hampered by host cell background.

Another class of reporter genes which confer detectable characteristics on a host cell are those which encode polypeptides, generally enzymes, which render their transformants resistant against toxins, *e.g.*, the neo gene which protects host cells against toxic levels of the antibiotic G418 a gene encoding dihydrifolate reductase, which confers resistance to methotrexate or the chloramphenicol acetyltransferase (CAT) gene (Osborne *et al.*, *Cell*, 42:203- 212 (1985)). Resistance to antibiotic or toxin requires days of culture to confirm, or complex assay procedures if other than a biological determination is to be made.

Other genes for use in the screening assay herein are those capable of transforming hosts to express unique cell surface antigens, *e.g.*, viral env proteins such as HIV gp120 or herpes gD, which are readily detectable by immunoassays. The polypeptide products of the reporter gene are secreted, intracellular or, as noted above, membrane bound polypeptides. If the polypeptide is not ordinarily secreted it is fused to a heterologous signal sequence for processing and secretion. In other circumstances, the signal is modified in order to remove sequences that interdict secretion. For example, the herpes gD coat protein has been modified by site directed deletion of its transmembrane binding domain, thereby facilitating its secretion (*See*, EP 139,417A). This truncated form of the herpes gD protein is detectable in the culture medium by conventional immunoassays. Preferably, however, the products of the reporter gene are lodged in the intra-cellular or membrane compartments. Then they can be fixed to the culture container, *e.g.* microtiter

wells, in which they are grown, followed by addition of a detectable signal generating substance such as a chromogenic substrate for reporter enzymes.

b. Linkage of PPAR γ gene control regions to reporters

5 In general, a PPAR γ gene promoter is employed to control transcription and hence influence expression of the reporter gene. The PPAR γ gene promoter is optionally combined with more potent promoters, *e.g.* the TK or SV40 early promoter, in order to increase the sensitivity of the screening assay.

10 A preferred condition would be to use the sequences upstream or 5' to the transcription initiation site or the coding sequence as the control elements, with or without additional promoter elements such as a TATA sequence or other sequences as may be required and obvious to one practiced in the art of heterologous gene expression and with or without intron sequences fused to a reporter gene to measure the effects of candidate compounds added to the cell culture.

15 The PPAR γ gene promoter, whether a hybrid or the native PPAR γ gene promoter, is ligated to DNA encoding the reporter gene by conventional methods. The PPAR γ gene promoter is obtained by in vitro synthesis or recovered from genomic DNA. It is ligated into proper orientation (5' to 3') adjacent 5' to the start codon of the reporter gene with or without additional control elements. The region 3' to the coding sequence for the reporter
20 gene will contain a transcription termination and polyadenylation site, for example, the hepatitis B or SV40 polyA site. The promoter and reporter gene are inserted into a replicable vector and transfected into a cloning host such as *E. coli*, the host cultured and the replicated vector recovered in order to prepare sufficient quantities of the construction for later transfection into suitable eukaryotic host.

25 The screening assay typically is conducted by growing the PPAR γ gene promoter transformants (*e.g.* stably transformed) to a suitable state of confluency in microtiter wells, adding the candidate compounds to a series of wells, and determining the signal level after an incubation period that is sufficient to demonstrate a measurable signal in the assay system chosen. The wells containing varying proportions of candidates are then evaluated
30 for signal activation. Candidates that demonstrate dose related enhancement of reporter

gene transcriptions or expression are then selected for further evaluation as clinical therapeutic agents. Candidate compounds may be useful therapeutic agents that would modulate PPAR γ gene expression.

2. Transgenic Animals and Gene therapy

Transgenic animals can be used in lieu of cultured cells for screening assays of this invention. The human PPAR γ control regions may be introduced into animals by transgenic techniques, such as those disclosed in PCT publication WO 94/18959, incorporated by reference herein.

Transgenic mice carrying a cloned human PPAR γ gene can be used both as a primary screening vehicle in which compounds can be administered and parameters sensitive to changes in expression of the PPAR γ gene such as PPAR γ mRNA production can be measured along with other appropriate controls to effectively assess the changes in expression of the PPAR γ gene as well as a means of corroborating primary compound positives.

Alternatively, the cloned human PPAR γ gene can be introduced into animals utilizing adenovirus drag technology in which the target DNA is admixed with poly-L-lysine and/or transferrin or asialoglycoprotein modified adenovirus and injected into the animal, resulting in expression of the foreign DNA (Wu *et al.*, *JBC* 266:14338-14342, (1991); Yanow *et al.*, *PNAS* 90:2122-2126 (1993)). In a preferred embodiment, recombinant adenovirus carrying the exogenous DNA can be injected directly into fat deposits of mice, rats or other species as has been done previously in brain (Davidson, *Nature Genetics* 3:219, *Science* 259:988), muscle (Quantin, *PNAS* 89:2581, Statford-Perricaudet *J. Clin. Invest.* 90:626), and tumors. These animal model assay systems are also useful in secondary characterization and study of compounds found to regulate human PPAR γ gene expression identified in other assays. Additionally, the coding region of the PPAR γ gene can be replaced with a reporter coding sequence as described above which could be then introduced into animals either via the standard transgenic practice or through the use of adenoviral drag or other methods of introducing foreign DNA into animals.

30 A variety of methods are available for the production of transgenic animals

associated with this invention. DNA can be injected into the pronucleus of a fertilized egg before fusion of the male and female pronuclei, or injected into the nucleus of an embryonic cell (e.g., the nucleus of a two-cell embryo) following the initiation of cell division (Brinster *et al.*, Proc. Nat. Acad. Sci. USA 82: 4438-4442 (1985)). Embryos can
5 be infected with viruses, especially retroviruses, modified to carry inorganic-ion receptor nucleotide sequences of the invention.

Pluripotent stem cells derived from the inner cell mass of the embryo and stabilized in culture can be manipulated in culture to incorporate nucleotide sequences of the invention. A transgenic animal can be produced from such cells through implantation
10 into a blastocyst that is implanted into a foster mother and allowed to come to term. Animals suitable for transgenic experiments can be obtained from standard commercial sources such as Charles River (Wilmington, MA), Taconic (Germantown, NY), Harlan Sprague Dawley (Indianapolis, IN), etc.

The procedures for manipulation of the rodent embryo and for microinjection of
15 DNA into the pronucleus of the zygote are well known to those of ordinary skill in the art (Hogan *et al.*, *supra*). Microinjection procedures for fish, amphibian eggs and birds are detailed in Houdebine and Chourrout, Experientia 47: 897-905 (1991). Other procedures for introduction of DNA into tissues of animals are described in U.S. Patent No., 4,945,050 (Sandford *et al.*, July 30, 1990).

20 By way of example only, to prepare a transgenic mouse, female mice are induced to superovulate. Females are placed with males, and the mated females are sacrificed by CO₂ asphyxiation or cervical dislocation and embryos are recovered from excised oviducts. Surrounding cumulus cells are removed. Pronuclear embryos are then washed and stored until the time of injection. Randomly cycling adult female mice are paired with
25 vasectomized males. Recipient females are mated at the same time as donor females.

Embryos then are transferred surgically. The procedure for generating transgenic rats is similar to that of mice. See Hammer *et al.*, *Cell* 63:1099-1112 (1990).

Methods for the culturing of embryonic stem (ES) cells and the subsequent production of transgenic animals by the introduction of DNA into ES cells using methods such as electroporation, calcium phosphate/DNA precipitation and direct injection also are well known to those of ordinary skill in the art. See, for example, Teratocarcinomas and Embryonic Stem Cells, A Practical Approach, E.J. Robertson, ed., IRL Press (1987).

In cases involving random gene integration, a clone containing the sequence(s) of the invention is co-transfected with a gene encoding resistance. Alternatively, the gene encoding neomycin resistance is physically linked to the sequence(s) of the invention. Transfection and isolation of desired clones are carried out by any one of several methods well known to those of ordinary skill in the art (E.J. Robertson, *supra*).

DNA molecules introduced into ES cells can also be integrated into the chromosome through the process of homologous recombination. Capecchi, *Science* 244: 1288-1292 (1989). Methods for positive selection of the recombination event (*i.e.*, neo resistance) and dual positive-negative selection (*i.e.*, neo resistance and gancyclovir resistance) and the subsequent identification of the desired clones by PCR have been described by Capecchi, *supra* and Joyner *et al.*, *Nature* 338: 153-156 (1989), the teachings of which are incorporated herein. The final phase of the procedure is to inject targeted ES cells into blastocysts and to transfer the blastocysts into pseudopregnant females. The resulting chimeric animals are bred and the offspring are analyzed by Southern blotting to identify individuals that carry the transgene. Procedures for the production of non-rodent mammals and other animals have been discussed by others. See Houdebine and Chourrout, *supra*; Pursel *et al.*, *Science* 244:1281-1288 (1989); and Simms *et al.*, *Bio/Technology* 6:179-183 (1988).

Where a modulator of a PPAR γ control region is a protein (e.g., ADD-1/SREBP-1), the modulator can be introduced into relevant cells in a host by gene therapy (reviewed in Miller, *Nature* 357:455-460, (1992). In addition, the human PPAR γ control regions can be operably linked to a wild type or mutant PPAR γ coding sequence and inserted into a host for expressing the wild type or mutant PPAR γ gene. The human PPAR γ control

regions can also be operably linked to a different gene and inserted into a host for tissue specific expression under the regulation of the human PPAR γ control regions. An *in vivo* model of gene therapy for human severe combined immunodeficiency is described in Ferrari, et al., *Science* 251:1363-1366, (1991). The basic science of gene therapy is
5 described in Mulligan, *Science* 260:926-931, (1993).

In one preferred embodiment, an expression vector containing the hPPAR γ control region is inserted into cells, the cells are grown *in vitro* and then infused in large numbers into patients.

The gene therapy may involve the use of an adenovirus containing the target DNA,
10 implantation of engineered cells, or injection of naked DNA into appropriate tissues.

Expression vectors derived from viruses such as retroviruses, vaccinia virus, adenovirus, adeno-associated virus, herpes viruses, several RNA viruses, or bovine papilloma virus, may be used for delivery of nucleotide sequences (e.g., cDNA) into the targeted cell population (e.g., tumor cells). Methods well known to those skilled in the art
15 can be used to construct recombinant viral vectors containing coding sequences. See, for example, the techniques described in Maniatis et al., Molecular Cloning: A Laboratory Manual, Cold Spring Harbor Laboratory, N.Y. (1989), and in Ausubel et al., Current Protocols in Molecular Biology, Greene Publishing Associates and Wiley Interscience, N.Y. (1989). Alternatively, recombinant nucleic acid molecules encoding protein
20 sequences can be used as naked DNA or in reconstituted system e.g., liposomes or other lipid systems for delivery to target cells (See e.g., Felgner et al., *Nature* 337:387-8, 1989). Several other methods for the direct transfer of plasmid DNA into cells exist for use in human gene therapy and involve targeting the DNA to receptors on cells by complexing the plasmid DNA to proteins. See, Miller, *supra*.

In its simplest form, gene transfer can be performed by simply injecting minute amounts of DNA into the nucleus of a cell, through a process of microinjection. Capecchi MR, Cell 22:479-88 (1980). Once recombinant genes are introduced into a cell, they can be recognized by the cell's normal mechanisms for transcription and translation, and a gene product will be expressed. Other methods have also been attempted for introducing
30 DNA into larger numbers of cells. These methods include: transfection, wherein DNA is

precipitated with CaPO_4 and taken into cells by pinocytosis (Chen C. and Okayama H, Mol. Cell Biol. 7:2745-52 (1987)); electroporation, wherein cells are exposed to large voltage pulses to introduce holes into the membrane (Chu G. et al., Nucleic Acids Res., 15:1311-26 (1987)); lipofection/liposome fusion, wherein DNA is packaged into lipophilic vesicles which fuse with a target cell (Felgner PL., et al., Proc. Natl. Acad. Sci. USA. 84:7413-7 (1987)); and particle bombardment using DNA bound to small projectiles (Yang NS. et al., Proc. Natl. Acad. Sci. 87:9568-72 (1990)). Another method for introducing DNA into cells is to couple the DNA to chemically modified proteins.

It has also been shown that adenovirus proteins are capable of destabilizing endosomes and enhancing the uptake of DNA into cells. The admixture of adenovirus to solutions containing DNA complexes, or the binding of DNA to polylysine covalently attached to adenovirus using protein crosslinking agents substantially improves the uptake and expression of the recombinant gene. Curiel DT et al., Am. J. Respir. Cell. Mol. Biol., 6:247-52 (1992).

As used herein "gene transfer" means the process of introducing a foreign nucleic acid molecule into a cell. Gene transfer is commonly performed to enable the expression of a particular product encoded by the gene. The product may include a protein, polypeptide, anti-sense DNA or RNA, or enzymatically active RNA. Gene transfer can be performed in cultured cells or by direct administration into animals. Generally gene transfer involves the process of nucleic acid contact with a target cell by non-specific or receptor mediated interactions, uptake of nucleic acid into the cell through the membrane or by endocytosis, and release of nucleic acid into the cytoplasm from the plasma membrane or endosome. Expression may require, in addition, movement of the nucleic acid into the nucleus of the cell and binding to appropriate nuclear factors for transcription.

As used herein "gene therapy" is a form of gene transfer and is included within the definition of gene transfer as used herein and specifically refers to gene transfer to express a therapeutic product from a cell *in vivo* or *in vitro*. Gene transfer can be performed *ex vivo* on cells which are then transplanted into a patient, or can be performed by direct administration of the nucleic acid or nucleic acid-protein complex into the patient.

In all of the preceding vectors set forth above, a further aspect of the invention is

that the nucleic acid sequence contained in the vector may include additions, deletions or modifications to some or all of the sequence of the nucleic acid, as defined above.

In another preferred embodiment, a method of gene replacement is set forth. "Gene replacement" as used herein means supplying a nucleic acid sequence which is capable of being expressed *in vivo* in an animal and thereby providing or augmenting the function of an endogenous gene which is missing or defective in the animal.

3. Example 1: Identifying a Modulator of Human PPAR γ

The following example identifies a transcription modulator of human PPAR γ .

- 10 a. ADD-1/SREBP-1 regulates hPPAR γ transcription through
 an E-box motif in the hPPAR γ 3 promoter

Sequence analysis of the hPPAR γ 3 promoter region revealed the presence of a putative E-box binding site for ADD-1/SREBP-1 protein at position -342, which we defined as the PPAR γ 3-E-box. In order to demonstrate direct binding of ADD-1/SREBP-1 to the PPAR γ 3-E-box, we used double-stranded oligonucleotides corresponding to the PPAR γ 3-E-box (LF-102) as a probe in EMSA. Baculovirus-produced and partially purified ADD-1/SREBP-1 is capable of binding to this site. Competition assays using increasing amounts of either a cold double-stranded oligonucleotide containing the PPAR γ 3-E-box, a consensus 3-hydroxy-3-methylglutaryl coenzyme A synthase SRE (Smith *et al.*, *J. Biol. Chem.* 263:18480-18487 (1988)), or the mutated PPAR γ 3-E-boxmut were performed in order to demonstrate the specificity of the binding. Binding of ADD-1/SREBP-1 to the PPAR γ 3-E-box is competed by both the cold PPAR γ 3-E-box, and by the consensus SRE oligonucleotides (Smith *et al.*, *J. Biol. Chem.* 263:18480-18487 (1988)), whereas the mutated PPAR γ 3-E-boxmut oligonucleotide was unable to compete with the PPAR γ 3-E-box for binding of SREBP-1. Similar data were obtained when in vitro translated ADD-1/SREBP-1 protein was used instead of baculovirus-produced protein.

To assess whether ADD-1 regulates the expression of the hPPAR γ 3 mRNA, we co-transfected either an expression plasmid coding for ADD-1 together with the pGL3y3p800

luciferase reporter vector. When Hep G2 cells were cotransfected with the ADD-1 expression vector, the luciferase activity was increased at least 4-fold relative to the basal activity of the hPPAR γ 3 promoter. As a control we transfected the pGL3 γ 1p3000 and pGL3 γ 2p1000 expression plasmids, which contain respectively 3 kb and 1 kb of the

5 human PPAR γ 1 and γ 2 promoter (Fajas *et al.*, *J. Biol. Chem.* 272:18779-18789 (1997)). Activity of these two reporter constructs was unaffected when the ADD-1 expression vector was cotransfected, suggesting that the effect on the PPAR γ 3 promoter was specific. To unequivocally demonstrate that it is through binding to the PPAR γ 3-E-box that ADD-

10 1 stimulates the activity of the hPPAR γ 3 promoter, we substituted three bases in the PPAR γ 3-E-box (from ATTCATGTGACAT to ATTCATGCATCAT) to generate the pGL3 γ 3p800-E-boxmut reporter plasmid. Cotransfected ADD-1 is unable to stimulate the mutated pGL3 γ 3p800-E-boxmut reporter vector in Hep G2 cells, whereas in the same experiment, the wild-type promoter is induced by 4-fold. Qualitatively similar results were obtained when an expression vector for mouse SREBP-1a was used.

15 Next, we evaluated the activity of the various PPAR γ promoters in cholesterol depleted cells, a condition which is known to stimulate the proteolytic activation of ADD-1/SREBP-1 (Sakai *et al.*, *Cell* 85:1037-1046 (1996); Shimomura *et al.*, *Proc. Natl. Acad. Sci. USA* 94:12345-12359 (1997); Wang *et al.*, *Cell* 77:53-62 (1994)). Cells were therefore transfected with the pGL3 γ 3p800, pGL3 γ 2p1000, and pGL3 γ 1p3000 reporter vectors and

20 then incubated in the presence or absence of cholesterol in the media. The PPAR γ 3 promoter construct was significantly induced (2-fold) when the cells were maintained in cholesterol-depleted medium. No effect of cholesterol was observed when the pGL3 γ 3p800-E-boxmut reporter vector, in which the E box was mutated, was used, suggesting that the induction of the PPAR γ 3 promoter observed upon depletion of

25 cholesterol is mediated by ADD-1/SREBP-1. The pGL3 γ 2p1000 and pGL3 γ 1p3000 promoter reporter constructs, which were not induced by ADD-1/SREBP-1 cotransfection, were also unresponsive to cholesterol depletion. This assay can be used to screen for other transcription modulators of PPAR γ 1, 2, and 3.

b. Ectopically expressed ADD-1/SREBP-1 induces PPAR γ mRNA expression.

To investigate whether ADD-1/SREBP-1 expression was sufficient to regulate the expression of the endogenous PPAR γ 3 mRNA, Hep G2 cells were electroporated with
5 vectors expressing either SREBP-1a (Yokoyama *et al.*, *Cell* 75:187-197 (1993)) or ADD-1 (Tontonoz *et al.*, *Mol. Cell. Biol.* 13:4753-4759 (1993)). RNA was extracted 48 hr after transfection and analysed by RNase protection assay for the presence of PPAR γ mRNA. PPAR γ 3 mRNA levels were significantly elevated (at least 2-fold) in the cells transfected either with SREBP-1a or with ADD-1, whereas no induction of PPAR γ 3 mRNA was
10 detected in cells transfected with an empty expression vector. Interestingly, PPAR γ 1 mRNA, which was expressed to a much higher level under basal conditions relative to PPAR γ 3, was also increased (approximately 3-fold) with either the SREBP-1a or ADD-1 expression vectors. This demonstrates that ADD-1/SREBP-1 controlled not only the transcription of the PPAR γ 3 promoter but also that of the other more distant PPAR γ
15 promoters. These results suggest that the increased PPAR γ expression in response to cholesterol depletion is the result of an increased transcriptional activity of the PPAR γ 3 promoter.

To study the effects of ADD-1 on PPAR γ expression in more detail, either an empty retroviral vector pBabe or the same vector encoding for full length ADD-1 or the
20 superactive ADD-1-403 form were introduced into 3T3-L1 cells via retroviral infection. Northern blot analysis showed that retroviral infection, by the virus encoding for ADD-1, resulted in a two-fold higher level of ADD-1 expression. Infected cells were then cultured to confluence and consecutively treated with differentiation medium. Total RNA was isolated at confluence (preadipocytes) and at day 6 after confluence (adipocytes) from the
25 cells expressing either the empty pBabe vector or the same vector encoding for ADD-1 or ADD-1-403, a truncated form of ADD-1, equivalent to the proteolytically activated protein, which lacks the membrane anchoring domain. RNase protection assay indicated that the expression of PPAR γ mRNA was induced in both 3T3-L1 preadipocytes and adipocytes which ectopically express ADD-1. The effect of retroviral infection was more

pronounced in 3T3-L1 adipocytes relative to preadipocytes. Interestingly, ADD-1-403, which lacks the membrane anchoring domain, was significantly more active in inducing PPAR γ expression. These results suggest that the adipogenic effects of ADD-1/SREBP-1 previously demonstrated (Kim and Spiegelman, *Genes & Dev.* 10:1096-1107 (1996)) are at least in part due to an up-regulation of the PPAR γ gene expression.

- c. PPAR γ expression is induced in cells grown under conditions which stimulate ADD-1/SREBP-1 activity.

Next, the possibility that PPAR γ was also induced under more physiological conditions, associated with activation of ADD-1/SREBP-1, was evaluated. To do this we quantified the relative expression of PPAR γ protein by western blot analysis in undifferentiated 3T3-L1 and Hep G2 cells grown in medium containing different cholesterol concentrations (Wang *et al.*, *Cell* 77:53-62 (1994)). In both cell lines, PPAR γ protein was significantly induced upon cholesterol depletion for 24 hours, a condition known to enhance the production of mature and active ADD-1/SREBP-1 (Sakai *et al.*, *Cell* 85:1037-1046 (1996); Wang *et al.*, *Cell* 77:741-750 (1994)). Interestingly, PPAR γ protein levels were decreased acutely by readdition of cholesterol (10 μ M) and 25-hydroxycholesterol (1 μ M) to the culture medium for 6 hours. These results suggest that PPAR γ expression is subject to a tight and fast control by alterations in intracellular cholesterol levels.

Treatment with HMG-CoA reductase inhibitors, which inhibit the enzyme responsible for the rate-limiting step of cholesterol synthesis, provide another way to modify cellular cholesterol levels. Upon treatment, with compounds such as compactin or simvastatin, cells will become cholesterol depleted and the production of the active forms of ADD-1/SREBP-1 will increase (Sakai *et al.*, *Cell* 85:1037-1046 (1996); Shimomura *et al.*, *Proc. Natl. Acad. Sci. USA* 94:12345-12359 (1997)). Therefore, the expression of PPAR γ protein was evaluated in Hep G2 cells before and after treatment with the potent HMG-CoA reductase inhibitor, simvastatin. Treatment of the cells with simvastatin (5×10^{-7} M) during 6 hours resulted in a robust and fast induction of PPAR γ protein levels (4-fold), which was sustained 12 hours after addition.

d. PPAR γ activity is stimulated by activation of ADD-1/SREBP-1.

Next we wanted to assess whether the above-mentioned changes in PPAR γ expression were associated with changes in the capabilities of PPAR γ to transactivate. A PPRE-driven luciferase reporter gene, containing three copies of the apo A-II J site (Vu-Dac *et al.*, 1995), ie. J3-TK-LUC, was transfected into rabbit kidney-derived RK-13 cells and half of the cells were maintained in cholesterol-depleted medium whereas the other half was grown in the same medium supplemented with a mixture of cholesterol and 25-hydroxycholesterol. In both conditions increasing amounts of the synthetic PPAR γ ligand, BRL 49,653, were added to the medium, resulting in a dose-dependent activation of promoter activity by BRL 49,653. Under conditions of cholesterol depletion, the reporter gene was, however, activated to a significantly higher level. In fact, the BRL 49,653 dose-response curve was shifted proportionally, keeping the slope constant and suggesting that the observed effect of cholesterol depletion was the result of an increased expression of the PPAR γ protein. Similar results were obtained when 3T3-L1 and ob-1771 preadipocyte cells were used. In order to exclude the possibility that the observed effect was specific for the apo A-II PPRE, we performed a cotransfection experiment using a different luciferase reporter driven by a single copy of the PPRE from the acyl CoA oxidase (ACO) gene (ACO-TK-LUC;(Osumi *et al.*, *Biochem. Biophys. Res. Commun.* 175:866-871 (1991)).

Also the activity of the ACO-TK-LUC reporter was significantly induced by cholesterol depletion.

Finally, to demonstrate that ADD-1/SREBP-1 was mediating the observed increase in PPAR γ activity, the J3-TK-LUC reporter vector was cotransfected in 3T3-L1 cells together with an empty expression vector or an expression vector coding for either a constitutively active form of ADD-1, or a dominant negative form of ADD-1. When cells were cotransfected with the empty parental expression vector, a significant 1.5-fold induction of the luciferase activity was observed when the medium was depleted in cholesterol. In contrast, no effect of cholesterol depletion could be observed when cells were cotransfected with the dominant negative form of ADD-1, suggesting that the increased activity of PPAR γ in response of cholesterol depletion is mediated by ADD-1/SREBP-1. A significant, but somehow less important inductive effect of cholesterol depletion was observed when the cells were cotransfected with the constitutively active form of ADD-1, indicating that under this condition PPAR γ activity was at the limit of saturation.

Table I: Oligonucleotides used in this study listed from 5' to 3'.

	Name	Sequence ID No.	Sequence
5	LF-2	4	TCTCCGGTGTCTCGAGGCCGACCCAA
	LF-14	5	AGTGAAGGAATCGCTTTCTGGGTCAAT
	LF-18	6	AGCTGATCCCAAAGTTGGTGGGCCAGA
	LF-20	7	CATTCCATTACACAAGAACAGATCCAGTGGT
	LF-21	8	GGCTCTTCATGAGGCTTATTGTAGAGCTGA
10	LF-22	9	GCAATTGAATGTCGTGTCTGTGGAGATAA
	LF-23	10	GTGGATCCGACAGTTAAGATCACATCTGT
	LF-24	11	GTAGAAATAAATGTCAGTACTGTCGGTTTC
	LF-25	12	TCGATATCACTGGAGATCTCCGCCAACAG
	LF-26	13	ACATAAAGTCCTTCCCGCTGACCAAAGCAA
15	LF-27	14	CTCTGCTCCTGCAGGGGGGTGATGTGTTT
	LF-28	15	GAAGTTCAATGCACTGGAATTAGATGACA
	LF-29	16	GAGCTCCAGGGGTTGTAGCAGGTTGTCTT
	LF-33	17	GACGGGCTGAGGAGAAGTCACACTCTGA
	LF-35	18	AGCATGGAATAGGGGTTTGCTGTAATTC
20	LF-36	19	TAGTACAAGTCCTTGTAGATCTCC
	LF-44	20	GTCGGCCTCGAGGACACCGGAGAG
	LF-58	21	CACTCATGTGACAAGACCTGCTCC
	LF-59	22	GCCGACACTAAACCACCAATATAC
	LF-60	23	CGTTAAAGGCTGACTCTCGTTTGA
25	AII J PPRE	24	GATCCTTCAACCTTTACCCTGGTAGA
	ACO PPRE	25	GATCCCGAACGTGACCTTTGTCCTGGTCCC
	LPL PPRE	26	GATCCGTCTGCCCTTTCCCCCTCTTCA
	γ AS	27	GCATTATGAGCATCCCCAC
30	γ S	28	TCTCTCCGTAATGGAAGACC
	γ 2S	29	GCGATTCTTCACTGATAC
	CDS	30	TTCTAGAATTCAGCGGCCGC(T)30(G/A/C)(G/A/C/T)

Table II. Intron-exon boundaries of the PPAR γ exons

The nucleotides in the exon are indicated in uppercase letters, whereas the flanking nucleotides in the intron are in lowercase. The approximate size of the introns is indicated in kilobases, and the exact length in base pairs of the exons is indicated between brackets. Amino acids encoded by the nucleotides flanking the intron/exon border are indicated by their letter symbol. The stop codon is indicated by an asterisk.

	Exon (bp)	Donor/ (SEQ ID NO.)	Intron in kb	Acceptor/ (SEQ ID NO.)	Exon
10	A1 (97)	CGCAG gtcagagt..(43)	>20	..ttgttaag ATTTG (44)	A2
	A2 (74)	TAACG gtaagtaa.. (45)	>20	..ccttcag AA ATG (46)	1
15	B (211)	CAA G gtaaagtt.. (47)	21	..ccttcag AA ATG (48)	1
		Q		M E M	
20	1 (231)	CAA A gtatgatg.. (49)	1.6	..atacacag GT GCA (50)	2
		Q		S A	
	2 (170)	C AAG gtaattaa.. (51)	9.5	..cttgcag GGT T (52)	3
		K		G	
25	3 (139)	AAT G gtaagtaa.. (53)	10.7	..ctctatag CC ATC (54)	4
		N		A I	
	4 (203)	A TCA gttagttc.. (55)	10	..attgcag CCA T (56)	5
		S		P	
30	5 (451)	GGA G gtaagatt.. (57)	16.3	..ttccccag AC CGC (58)	6
		G		D R	
35	6 (248)	TAC TAG cagaga.. (59)			
		Y *			

F. Materials and Methods

1. Isolation of the Human PPAR γ cDNA and Gene, Restriction Mapping, Determination of Intron/Exon Boundaries, and DNA Sequencing

5 A human adipose tissue lambda gt11 library was screened with a random primed 32P-labeled 200 bp fragment, covering the DNA-binding domain of the mouse PPAR γ cDNA. After hybridization, filters were washed in $2 \times$ SSC, 0.1% SDS for 10 min at 20 °C and twice for 30 min in $1 \times$ SSC, 0.1% SDS at 50 °C and subsequently exposed to x-ray film (X-OMAT-AR, Kodak). Of several positive clones, one clone 407 was characterized
10 in detail. The insert of this clone, starting ± 90 bp upstream of the ATG start codon and extending downstream into the 3'-untranslated region (UTR) sequence, was subcloned in the EcoRI site of pBluescript SK - to generate clone 407.2. Sequence analysis of 407.2 confirmed it as being the human homologue of the mouse PPAR γ 2 cDNA. While this work was in progress, other groups also reported the isolation of human PPAR γ 2
15 cDNA clones (34, 35).

To isolate genomic P1-derived artificial chromosome (PAC) clones containing the entire human PPAR γ gene, the primer pair LF-3 and LF-14 was used to amplify an 86-bp probe with human genomic DNA as template. This fragment was then used to screen a PAC human genomic library from human foreskin fibroblasts. Three positive clones, P-
20 8854, P-8855, and P-8856, were isolated. Restriction digestion and Southern blotting were performed according to classical protocols as described by Sambrook *et al.* (36). Sequencing reactions were performed, according to the manufacturer instructions, using the T7 sequencing kit (Pharmacia Biotech Inc.).

2. Determination of the Transcription Initiation Sites: Primer Extension and 5'-Rapid Amplification of cDNA Ends (5'-RACE)

a. Primer Extension

5 The oligonucleotide LF-35 was ³²P-labeled with T4-polynucleotide kinase (Amersham Life Science, Inc) to a specific activity of 107 dpm/50 ng and purified by gel electrophoresis. For primer extension, 105 dpm of oligonucleotide was added in a final volume of 100 µl to 50 µg of adipose tissue total RNA isolated from different patients. Primer extension analysis was performed following standard protocols utilizing a mixture
10 of 1.25 units of avian myeloblastosis virus reverse transcriptase (Life Technologies, Inc.) and 100 units of Moloney murine leukemia virus reverse transcriptase (Life Technologies, Inc.). A sequencing reaction and molecular mass standards were used to map the 5'-end of the extension products.

b. 5'-RACE

15 The Marathon cDNA amplification kit (CLONTECH) was used to obtain a library of adaptor-ligated double-stranded cDNA from human adipose tissue. 1 µg of poly(A)+ RNA was used as a template for the first strand synthesis, with the 52-mer CDS primer and 100 units of the MMLV reverse transcriptase in a total volume of 10 µl. Synthesis was
20 carried out at 42 °C for 1 h. Next, the second strand was synthesized at 16 °C for 90 min in a total volume of 80 µl containing the enzyme mixture (RNase H, Escherichia coli DNA polymerase I, and E. coli DNA ligase), the second strand buffer, the dNTP mix, and the first strand reaction. cDNA ends were then made blunt by adding to the reaction 10 units
25 of T4 DNA polymerase and incubating at 16 °C for 45 min. The double-stranded cDNA was phenol/chloroform extracted, ethanol precipitated, and resuspended in 10 µl of water. Half of this volume was used to ligate the adaptor to the cDNA ends (adaptor sequence CTAATACGACTCACTATAGGGCTCGAGCGGCCGCGCCGGGCAGGT) in a total volume of 10 µl using 1 unit of T4 DNA ligase. The ligation reaction was incubated 16 h at 16 °C. The resulting cDNA library was diluted to a final concentration of 0.1 mg/ml.

30 The 5'-end of PPAR γ 1 PCR-amplified using 5 µl of the library as a template with

the oligonucleotides AP-1 (binding to the adaptor) and LF-45 (binding antisense to the 5'-end of the PPAR γ 1). After an initial denaturing step at 95 °C for 3 min, 25 cycles were done at the following conditions: 10 s at 95 °C, 20 s at 60 °C, and 30 s at 72 °C. The resulting PCR product was reamplified for 30 additional cycles at the same conditions using the nested oligonucleotides AP2 (nested to AP1) and LF-2 (nested to LF-45). The PCR product was analyzed on a 2% agarose gel, treated with Pfu polymerase (Stratagene) and cloned into the EcoRV site of pBluescript SK+. A total of 20 white colonies were grown and sequenced from both ends using the oligonucleotides T3 and T7 (Dye Terminator Cycle sequencing kit, Applied Biosystems).

For the determination of the 5'-end of PPAR γ 2, the same procedure was followed except that the oligonucleotide LF-14 (specific for the PPAR γ 2 5'-UTR) was used in the first round PCR, and the oligonucleotide LF-35 (nested to LF-14) was used in the second round PCR with the same cycling conditions.

3. Tissue Biopsies and Cell Culture

Omental adipose tissue, small and large intestine, kidney, muscle, and liver biopsies were obtained from non-obese adult subjects undergoing elective surgery or endoscopy. All subjects had fasted overnight before surgery (between 8.00 p.m. and 10 a.m.) and received intravenous saline infusion. They had given informed consent, and the project was approved by the ethics committee of the University of Lille. All tissue was immediately frozen in liquid nitrogen until RNA preparation.

Standard cell culture conditions were used to maintain 3T3-L1 (obtained from ATCC), CV-1 (a kind gift from Dr. R. Evans, Salk Institute, La Jolla, CA), and Hep G2 cells (ATCC). BRL-49,653, supplied by Ligand Pharmaceuticals, San Diego, CA (in DMSO) and fatty acids (in ethanol) were added to the medium at the concentrations and times indicated. Control cells received vehicle only. Fatty acids were complexed to serum albumin contained in delipidated and charcoal-treated fetal calf serum by preincubation for 45 min at 37 °C.

In Example 1, standard cell culture conditions were used to maintain 3T3-L1 (obtained from ATCC), HeLa (ATCC), CaCo2 (ATCC), RK-13 (ATCC), THP-1

(ATCC), and Hep G2 cells (ATCC). BRL 49,653 and simvastatin were dissolved in DMSO and cholesterol and 25-hydroxycholesterol in ethanol. Control cells received vehicle only. Retroviral infection of 3T3-L1 cells was performed as described previously (Kim and Spiegelman, *Genes & Dev.* 10:1096-1107 (1996)). Briefly, the BOSC23 cell line
5 was transiently transfected with the recombinant retroviral vectors pBabe, ADD-1-403, and ADD-1 (Kim and Spiegelman, *Genes & Dev.* 10:1096-1107 (1996)) using the calcium phosphate method. Viral supernatants were collected 48 hours after transfection and titrated. 3T3-L1 cells were incubated with retrovirus for 5 hours in the presence of 4 μ g/ml of polybrene. Cells were then subcultured (1:3) for 2 days after infection in medium
10 containing puromycin (2 μ g/ml) for selection. Differentiation of 3T3-L1 cells was as described previously (Lin and Lane, *Genes & Dev.* 6:533-544 (1992)).

4. mRNA Analysis by RT-Competitive PCR Assay

RNA preparation of total cellular RNA was performed as described previously
15 (37). The absolute mRNA concentration of the differentially spliced PPAR γ variants was measured by reverse transcription reaction followed by competitive polymerase chain reaction (RT-competitive PCR) in the presence of known amounts of competitor DNA yielding amplicons of different size allowing the separation and the quantification of the PCR products. The competitor was constructed by deletion of a 74-bp fragment
20 (nucleotides +433 to +507 by HindIII digestion) of PPAR γ 1 cloned into pBluescript KS+, yielding pBSCompPPAR γ . Working solution of the competitor was prepared by in vitro transcription followed by serial dilution in 10 mM Tris-HCl (pH 8.3), 1 mM EDTA buffer. For RT-competitive PCR, the antisense primer hybridized to the 3'-end of exon
3 (gammaAS:5'-GCATTATGAGCATCCCCAC-3', nt +600 to +620) and the sense primer
25 to exon 1 (gammaS:5'-TCTCTCCGTAATGGAAGACC-3', nt +146 to +165) or to the B exon (gamma2S:5'-GCGATTCCTTCACTGATAC-3', nt +41 to +59). Therefore, the same competitor served to measure either total PPAR γ mRNAs (γ 1 + γ 2; with primers gamma AS and gamma S) or, specifically, PPAR γ 2 mRNA (with primers gamma AS and gamma 2S). The gamma AS/gamma S primer pair gave PCR products of 474 and 400 bp for the
30 PPAR γ mRNAs and competitor, respectively. The primer pair gammaAS/gamma2S gave

580 bp for PPAR γ 2 mRNA and 506 bp for the competitor. For analysis of the PCR products, the sense primers gamma S and gamma2S were 5'-end labeled with the fluorescent dye Cy-5 (Eurogentec, Belgium).

First-strand cDNA synthesis was performed from total RNA (0.1 μ g) in the presence of the antisense primer gamma AS (15 pmol) and of thermostable reverse transcriptase (2.5 units; Tth DNA polymerase, Promega) as described (38). After the reaction, half of the RT volume was added to the PCR mix (90 μ l) containing the primer pair gamma AS/gamma S for the assay of PPAR γ total mRNA, whereas the other half was added to a PCR mix (10 mM Tris-HCl, pH 8.3, 100 mM KCl, 0.75 M EGTA, 5% glycerol, 0.2 mM dNTP, 5 units of Taq polymerase) containing the primer pair gammaAS/gamma2S for the assay of PPAR γ 2 mRNA. Four aliquots (20 μ l) of the mixture were then transferred to microtubes containing a different, but known, amount of competitor. After 120 s at 95 °C, the samples were subjected to 40 PCR cycles (40 s at 95 °C, 50 s at 55 °C, and 50 s at 72 °C). The fluorescent-labeled PCR products were analyzed by 4% denaturing polyacrylamide gel electrophoresis using an automated laser fluorescence DNA sequencer (ALFexpress, Pharmacia, Uppsala, Sweden), and integration of the area under the curve using the Fragment manager software (Pharmacia) was performed as described (38).

To validate this technique, human PPAR γ 2 mRNA was synthesized by in vitro transcription from the expression vector pSG5hPPAR γ (Riboprobe system, Promega) and quantified by competitive PCR over a wide range of concentrations (0.25-25 attomole (amol) added in the RT reaction). Standard curves were obtained in assaying PPAR γ total mRNA or PPAR γ 2 mRNA. The linearity ($r = 0.99$) and the slopes of the standard curves (0.98 and 1.11) indicated that the RT-competitive PCR is quantitative and that all the mRNA molecules are copied into cDNA during the RT step. The lower limit of the assay was about 0.05 amol of mRNA in the RT reaction, and the interassay variation of the RT-competitive PCR was 7% with six separated determinations of the same amount of PPAR γ mRNA.

5. Western Blot Analysis of PPAR γ

Cells and tissues were homogenized in a lysis buffer of PBS containing 1% Triton X-100 (Sigma). Tissues were homogenized in extraction buffer containing PBS and 1% Nonidet P-40 (Sigma), 0.5% sodium deoxycholate (Sigma), 0.1% SDS (Sigma). Fresh
5 mixture protease inhibitor (ICN) was added (100 mg/ml AEBSF, 5 mg/ml EDTA, 1 mg/ml leupeptin, 1 mg/ml pepstatin). Protein extracts were obtained by centrifugation of the lysate at 4 °C, and concentration was measured with the Bio-Rad DC Protein colorimetric assay system.

Protein (100 μ g) was separated by SDS-PAGE, transferred to nitrocellulose
10 membrane (Amersham Life Science, Inc.), and blocked overnight in blocking buffer (20 mM Tris, 100 mM NaCl, 1% Tween-20, 10% skim milk). Filters were first incubated for 4 h at room temperature with rabbit IgG anti-mPPAR γ (10 mg/ml), raised against an N-terminal PPAR γ peptide (amino acids 20-104), and next developed for 1 h at room
15 temperature with a goat anti-rabbit IgG (whole molecule) peroxidase conjugate (Sigma) diluted at 1/500. The complex was visualized with 4-chloro-1-naphtol as reagent.

In Example 1, the membranes were blocked overnight in blocking buffer (20 mM Tris, 100 mM NaCl, 1% Tween-20, 10% skim milk). Filters were first incubated 4 hours at 21°C with either a rabbit IgG anti-mPPAR γ (10 mg/ml) (Fajas *et al.*, *J. Biol. Chem.* 272:18779-18789 (1997)) or a rabbit IgG anti-mSREBP-1 antibody (Santa Cruz, CA), and
20 then for 1 hour at 21°C with a goat anti-rabbit IgG (whole molecule) peroxidase conjugate diluted at 1/5000. The complex was visualized with 4-chloro-1-naphtol as reagent.

6. Analysis of Promoter Activity

To test the activity of the human PPAR γ promoters several reporter constructs were made.

- A 1-kb fragment of PAC clone 8856 was isolated by PCR using the
5 oligonucleotides LF-35 (binding antisense in the PPAR γ 2 5'-UTR) and the oligonucleotide LF-58 (binding sense at position -1000 of the PPAR γ 2), was sequenced, and was inserted into EcoRV site of pBluescript (Stratagene, La Jolla, CA). After digestion of plasmid pBS γ 2p1000 with SmaI and KpnI, the insert was cloned into the reporter vector pGL3 (Promega), creating the expression vector pGL3 γ 2p1000.
- 10 To isolate the PPAR γ 1 promoter, an 8-kb EcoRI fragment, which hybridized with the oligonucleotide LF-2 (corresponding to the 5'-UTR of γ 1), was cloned into pBluescript. Partial mapping and sequencing of this clone revealed the presence of a 3-kb fragment upstream of the transcription initiation site. To test for promoter activity, a SacI/XhoI digestion of this clone containing the 3-kb promoter was inserted in the same
15 sites of pGL3, resulting in the final vector pGL3 γ 1p3000. The pSG5-haPPAR γ (39) and pMSV-C/EBP β (10) expression vectors were described elsewhere. Transfections were carried out in 60-mm plates using standard calcium phosphate precipitation techniques (for 3T3-L1, CV-1, and COS cells) (22). Luciferase and β -galactosidase assays were carried out exactly as described previously (22).
- 20 The PAC clone P-8856 (Fajas *et al.*, *J. Biol. Chem.* 272:18779-18789 (1997)), containing the full length PPAR γ gene, was also sequenced with the oligonucleotides LF-60 and LF-63 pointing upstream of exon A2. A 800 bp fragment of the PAC clone 8856 was isolated by PCR using the amplimers LF-60 (binding to the antisense strand in exon A2) and LF-68 (binding sense at position -800 of the PPAR γ 3 promoter). This PCR
25 fragment was sequenced, inserted into the EcoRV site of pBluescript SK+ (Stratagene, La Jolla, USA), and after SpeI and KpnI restriction subcloned into pGL3 (Promega, Madison, USA), creating the reporter vector pGL3 γ 3p800.

Site-directed mutagenesis of the E-box in the PPAR γ 3 promoter was performed by

splicing overlapping ends polymerase chain reaction (Ho, *et al.*, *Gene* 77:51-59 (1989)), using the oligo pairs LF-106/LF-60 and LF-107/LF-68, to generate the plasmid pGL3 γ 3p800-E-boxmut. This changed the three bases underlined in the sequence 5'-ATTCATGTGACAT-3' to 5'-ATTCATGCATCAT-3'. The J3-TK-LUC (Vu-Dac *et al.*, 5 1995) and ACO-TK-LUC (Osumi *et al.*, *Biophys. Res. Commun.* 175:866-871 (1991)) luciferase reporter vectors and the expression vectors encoding for ADD-1, a dominant negative form of ADD-1, and SREBP-1a (Tontonoz *et al.*, *Mol. Cell. Biol.* 13:4753-4759 (1993)); Yokoyama *et al.*, *Cell* 75:187-197 (1993)) were described before. Transfections, luciferase and β -galactosidase assays were generally performed as described previously 10 (Schoonjans *et al.*, *J. Biol. Chem.* 270:19269-19276 (1995)). To analyze the effect of cholesterol depletion in transfection experiments, the cells were divided in two pools after transfection. Half of the transfected cells were incubated with delipidated medium, whereas the other half of the cells were incubated with the same medium supplemented with a mixture of 10 μ M cholesterol and 1 μ M of 25-hydroxycholesterol.

15

7. Electrophoretic Mobility Shift Assays (EMSA) and Oligonucleotide Sequences

haPPAR γ (39), hPPAR γ 2, and mRXR α (40) proteins were synthesized in vitro in rabbit reticulocyte lysate (Promega). Molecular weights and quality of the in vitro 20 translated proteins were verified by SDS-PAGE. PPAR (2 μ l) and/or RXR (2 μ l) were incubated for 15 min on ice in a total volume of 20 μ l with 1-ng probe, 2.5 μ g of poly(dI-dC) and 1 μ g of herring sperm DNA in binding buffer (10 mM Tris-HCl pH 7.9, 40 mM KCl, 10% glycerol, 0.05% Nonidet P-40, and 1 mM dithiothreitol). For competition experiments, increasing amounts (from 10- to 200-fold molar excess) of cold 25 oligonucleotide (AII-J-PPRE, 5'-GATCCTTCAACCTTTACCCTGGTAGA-3' (41); acyl-CoA oxidase (ACO)-PPRE, 5'-GATCCCGAACGTGACCTTTGTCCTGGTCCC-3' (42); or LPL-PPRE, 5'-GATCCGTCTGCCCTTTCCCCCTCTTCA-3' (23)) were included just before adding T4-PNK end-labeled AII-J-PPRE oligonucleotide. DNA-protein complexes were separated by electrophoresis on a 4% polyacrylamide gel in 0.25 \times TBE buffer at 30 4 $^{\circ}$ C (43).

In Example 1, the SREBP-1a protein was produced in a baculovirus system and ADD-1 was produced by in vitro transcription. Quality of the produced proteins were verified by SDS-PAGE. Proteins were incubated for 15 min on ice in a total volume of 20 μ l with 1 ng of T4-PNK end-labelled double-stranded oligonucleotide containing the

5 PPAR γ 3 E-box (LF-102), 2.5 μ g poly (dI:dC) and 1 μ g herring sperm DNA in binding buffer (10 mM Tris-HCl (pH 7.9), 40 mM KCl, 10% glycerol, 0,05% Nonidet P-40 and 1 mM DTT). For competition experiments, increasing amounts of cold double-stranded oligonucleotides (10, 50-, and 100-fold molar excess) corresponding to the PPAR γ 3 E-box, the consensus 3-hydroxy-3-methylglutaryl coenzyme A synthase SRE site (Smith *et al.*, *J.*

10 *Biol. Chem.* 263:18480-18487 (1988)), or the mutated PPAR γ 3 E-box (LF-106) were included just before adding labelled oligonucleotide. DNA-protein complexes were separated by electrophoresis on a 4% polyacrylamide gel in 0.25 x TBE buffer at 4°C (Fried and Crothers, *Nucl. Acids Res.* 11:141-158 (1983)).

15 **8. RNA isolation, primer extension, and RNase protection assays**

In locating the promoter of PPAR γ 3, total cellular RNA was prepared as described previously (Saladin *et al.*, *Nature* 377:527-529 (1995)). For primer extension, the oligonucleotide LF-60 was 32P-labelled with T4-polynucleotide kinase (Amersham, Courtaboeuf, France) to a specific activity of 107 dpm/50 ng and purified by gel

20 electrophoresis. Primer extension analysis was performed using 50 μ g of total RNA and 105 dpm of radiolabelled oligonucleotide according to a standard protocol utilizing a mixture of 1.25 U AMV reverse transcriptase (Life technologies, Paisley, UK) and 100 U MMLV reverse transcriptase (Life technologies, Paisley, UK). A sequencing reaction was used as molecular mass standard to map the 5' end of the extension products.

The absolute mRNA concentration of the differentially spliced PPAR γ variants was measured by RNase protection assay exactly as described (Lemberger *et al.*, *J. Biol. Chem.* 271:1764-1769 (1995)). The full length PPAR γ 2 coding region plus 33 bp of the 5'UTR was amplified from human adipose tissue RNA by RT-PCR with the primer pair LF-3/LF-36 and was inserted in the inverted orientation (3' to 5' in front of the T7 promoter) into the EcoRI site of the expression vector pSG5 (Stratagene, La Jolla, CA). The resulting plasmid pSG5-hPPAR γ 2-inv was digested with EcoRV and religated, yielding the vector pSG5-hPPAR γ 2-RPA, which was used as a template for the synthesis of the anti-sense RNA probe, to measure the relative amounts of PPAR γ 2 relative to PPAR γ 1 and 3 mRNA.

For the specific analysis of the PPAR γ 3 mRNA relative to PPAR γ 1, another probe template was constructed by RT-PCR from human adipose tissue RNA with the primer pair LF-44 (which binds to the sense strand in exon A1) and LF-21 (which binds to the antisense strand in the exon 2). The amplified fragment, which contains part of exon A1, the full length exon A2, exon 1, and part of exon 2, was inserted into the EcoRV site of pBluescript SK+ to generate the plasmid pBS γ 3-RPA. For the analysis of mouse PPAR γ RNA, mPPAR γ cDNA was amplified, using the same strategy and oligonucleotides described above to create the vector pSG5-mPPAR γ 2-inv. This plasmid was digested by EcoRI and religated resulting in the plasmid pSG5-mPPAR γ -RPA. The in vitro synthesized probe contains part of the exons 4 and 5 of the mPPAR γ gene.

20

G. Candidate PPAR γ Modulators

The following molecules and their derivatives and homologs are candidate PPAR γ modulators:

- (1) HMG-CoReductase inhibitors, including, but not limited to, simvastatin, atorvastatin, pravastatin, and fluvastatin,
- (2) Cholesterol and its metabolites such as the various oxysterols,
- (3) Insulin and insulin mimetics,

25

- (4) Glucocorticoid hormones, including, but not limited to, cortisol, and dexamethasone,
- (5) Oxidized low density lipoproteins and their lipid components,
- (6) Agonists of receptors in the JAK-STAT pathway. Such agonists include, but
5 are not limited to, growth hormone, prolactin, leptin, and macrophage-cology stimulating factor (M-CSF), and
- (7) Phorbolsters such as PMA, and agonists of the cAMP pathway such as forskolin and dibutyryl cAMP.

Other candidate agents glucocorticoids; thyroid hormones; thyromimetics; fibrates,
10 free fatty acids and other agonists of PPAR including Di-(2-ethylhexyl)-phthalate, plasticizers and herbicides including 2, 4, 5-trichlorophenoxyacetic acid and leukotriene antagonists; antagonists of PPAR and PPAR subtype selective compounds; RAR selective agonists and antagonists including subtype selective compounds; RXR selective agonists and antagonists including subtype selective compounds; estrogens and other agonists and
15 antagonists of ER; androgens and other agonists and antagonists of AR; progestins and other agonists and antagonists of PR; non-steroid progestins; mineralocorticoids and other agonists and antagonists of MR; insulin; glucose; glucagon; free fatty acids; amino acids; sugars and other secretagogues including biguanides; antidiabetics including metformin and phenformin; pyroglyrides; linoglyrides and benzothenediones; non-steroidal anti-
20 inflammatory drugs; prostacyclins; prostaglandins; dihydroepiandrosterone and stimulators, precursors and derivatives thereof including Dioscorea and aloe vera, and extracts and compounds derived therefrom; tumor necrosis factors; cytokines and related signaling molecules; growth factors; fetuin; Amylin agonists and antagonists; prolactin; niacin; Acepimox and other nicotinic acid derivatives; triacins; amphetamines and derivatives
25 including fenfluramine and dexfenfluramine; endorphin antagonists; somatostatin; cholecystokinin; bombesin; gastrin; oral anti-diabetic agents; corticotropin releasing hormone; thiazolidinedione compounds; adrenocorticotrophic hormones; melanocyte stimulating hormone; gastric inhibitory peptide; growth hormone agonists and antagonists; α and β adrenergic agonists and antagonists including phenoxybenzamide; fluoxetine;
30 neuropeptide Y and modulators of its activity or expression; and the gene products of

agouti and GLP-1.

H. Utility of PPAR γ Modulators

A transcription modulator of PPAR γ can be used to treat or prevent disorders
5 involving tissues in which PPAR γ is expressed. The PPAR γ *gene* modulators identified by
the methods of this invention can be used to control a variety of physiological or
biochemical conditions in animals (esp. mammals) such as the level of metabolism, body
weight, food intake, oxygen consumption, body temperature, serum insulin level, serum
glucose level, and body fat content (versus muscle content). Such modulators are useful in
10 treating a host with an abnormal level of PPAR γ *gene* expression, as well as those having
normal levels of PPAR γ *gene* expression. The PPAR γ *gene* modulators can also be used
to treat diseases and conditions affected by the level of PPAR γ *gene* expression. The
modulators are useful in mimicking human diseases or conditions in animals relating to
the level of PPAR γ *gene* expression. The modulators can be used in experimental testing
15 of PPAR γ *gene* modulators for veterinary uses, including, but not limited to, controlling
the body weight of animals and the fat content of meat.

As we discussed above, PPAR γ regulates adipose tissue differentiation. In that
regard, a transcription modulator of PPAR γ can be used to treat or prevent diseases
associated with abnormalities of adipose tissue or adipocytes, including, but not limited to,
20 obesity, anorexia, cachexia, lipodystrophy, lipomas, liposarcomas, and abnormalities of
adipose tissue associated with anti-HIV treatment.

It has been known that PPAR γ agonists improve insulin sensitivity and ameliorate
glucose homeostasis and certain aspects of metabolism (*see* WO 97/10819, incorporated
by reference herein in its entirety). PPAR γ transcription modulators can be used to
25 achieve similar pharmaceutical effects. In that regard, this invention relates to methods of
identifying transcription modulators and using such modulators to treat or prevent insulin

resistance, diabetes mellitus (NIDDM), and conditions associated with insulin resistance such as polycystic ovary syndrome and lipodystrophy.

In a related application (PCT/US98/05852, incorporated by reference herein in its entirety), we showed that PPAR γ is strongly expressed in certain regions of the bowel and it plays a role in modulating gastrointestinal (GI) function and the development of GI tract cancer. In that regard, a transcription modulator of PPAR γ can be used to treat or prevent diseases of the GI tract, including, but not limited to, inflammatory bowel disease (*e.g.* Crohn's disease and ulcerative colitis), bowel cancer, irritable bowel syndrome, and ulcerations of the GI tract.

PPAR γ is expressed in macrophages and its expression is induced in foam cells, which are the initial cells of the atherosclerotic lesion (*see* Tontonoz P, *et al.*, *Cell* 93(2): 241-252 (1988); Nagy L, *et al.*, *Cell* 93(2): 229-240 (1988); and Ricote M, *et al.*, *Proc Natl Acad Sci USA* 95(13): 7614-7619 (1988)). In addition, activation of PPAR γ affects lipid levels in the blood and can reverse atherogenic lipid profiles. In that regard, a transcription modulator of PPAR γ can be used to treat or prevent hyper- and dyslipidemia, including but not limited to hypertriglyceridemia and hypo-alpha lipoproteinemia, atherosclerosis, and other vascular diseases.

We have observed that PPAR γ is highly expressed in eosinophils, which are involved in inflammatory and allergic responses. In addition, PPAR γ is highly expressed in other cells involved in host defense such as macrophages and neutrophils. Modulation of PPAR γ could affect these crucial cells and their role in immune and inflammatory reaction. Furthermore, the PPAR γ promoter contains several elements that are responsive to transcription factors activated under inflammatory conditions (such as STATs, NF-kB, C/EBPbeta, and AP-1). In that regard, a transcription modulator of PPAR γ can be used to treat or prevent acute inflammation (*e.g.*, septic shock, and infection), chronic inflammation (*e.g.*, inflammatory bowel disease, and rheumatoid arthritis), allergic conditions including conditions involving skin (*e.g.*, urticaria and eczema) and lungs

(asthma), immunologic disorders (*e.g.*, graft versus-host disease), parasitic infections, bacterial infections, and viral infections.

Because PPAR γ is highly expressed in cells involved in host defense, a modulator of PPAR γ expression can be used to enhance the host defense against malignant diseases, including, but not limited to, cancers such as cancer of the breast, prostate, and colon.

Accumulation of fat tissue in bone marrow is a common problem associated with or involved in the pathogenesis of osteoporosis and bone loss. In that regard, PPAR γ modulators (*esp.* a down modulator) can be used to prevent or treat osteoporosis and bone loss.

PPAR γ is involved in the differentiation of surfactant producing cells in the lung. By changing PPAR γ expression in these cells, PPAR γ modulators can be used to treat or prevent pulmonary disorders associated with abnormal surfactant production (*e.g.*, ARDS and RDS).

PPAR γ is expressed in certain regions of the skin. In that regard, modulators of PPAR γ can also be used to treat or prevent skin diseases involving those skin cells.

I. Pharmaceutical Formulations and Modes of Administration

The particular compound that affects the disorders or conditions of interest can be administered to a patient either by themselves, or in pharmaceutical compositions where it is mixed with suitable carriers or excipient(s). In treating a patient exhibiting a disorder of interest, a therapeutically effective amount of a agent or agents such as these is administered. A therapeutically effective dose refers to that amount of the compound that results in amelioration of symptoms or a prolongation of survival in a patient.

The compounds also can be prepared as pharmaceutically acceptable salts. Examples of pharmaceutically acceptable salts include acid addition salts such as those containing hydrochloride, sulfate, phosphate, sulfamate, acetate, citrate, lactate, tartrate, methanesulfonate, ethanesulfonate, benzenesulfonate, *p*-toluenesulfonate, cyclohexylsulfamate and quinate. (*See e.g.*, PCT/US92/03736). Such salts can be derived using acids such as hydrochloric acid, sulfuric acid, phosphoric acid, sulfamic acid, acetic acid, citric acid, lactic acid, tartaric acid, malonic acid, methanesulfonic acid,

ethanesulfonic acid, benzenesulfonic acid, *p*-toluenesulfonic acid, cyclohexylsulfamic acid, and quinic acid.

Pharmaceutically acceptable salts can be prepared by standard techniques. For example, the free base form of the compound is first dissolved in a suitable solvent such as
5 an aqueous or aqueous-alcohol solution, containing the appropriate acid. The salt is then isolated by evaporating the solution. In another example, the salt is prepared by reacting the free base and acid in an organic solvent.

Carriers or excipients can be used to facilitate administration of the compound, for example, to increase the solubility of the compound. Examples of carriers and excipients
10 include calcium carbonate, calcium phosphate, various sugars or types of starch, cellulose derivatives, gelatin, vegetable oils, polyethylene glycols and physiologically compatible solvents. In addition, the molecules tested can be used to determine the structural features that enable them to act on the *ob* gene control region, and thus to select molecules useful in this invention. Those skilled in the art will know how to design drugs from lead
15 molecules, using techniques such as those disclosed in PCT publication WO 94/18959, incorporated by reference herein.

Toxicity and therapeutic efficacy of such compounds can be determined by standard pharmaceutical procedures in cell cultures or experimental animals, *e.g.*, for determining the LD₅₀ (the dose lethal to 50% of the population) and the ED₅₀ (the dose
20 therapeutically effective in 50% of the population). The dose ratio between toxic and therapeutic effects is the therapeutic index and it can be expressed as the ratio LD₅₀/ED₅₀. Compounds which exhibit large therapeutic indices are preferred. The data obtained from these cell culture assays and animal studies can be used in formulating a range of dosage for use in human. The dosage of such compounds lies preferably within a range of
25 circulating concentrations that include the ED₅₀ with little or no toxicity. The dosage may vary within this range depending upon the dosage form employed and the route of administration utilized.

For any compound used in the method of the invention, the therapeutically effective dose can be estimated initially from cell culture assays. For example, a dose can be formulated in animal models to achieve a circulating plasma concentration range that includes the IC_{50} as determined in cell culture (i.e., the concentration of the test compound which achieves a half-maximal disruption of the protein complex, or a half-maximal inhibition of the cellular level and/or activity of a complex component). Such information can be used to more accurately determine useful doses in humans. Levels in plasma may be measured, for example, by HPLC.

The exact formulation, route of administration and dosage can be chosen by the individual physician in view of the patient's condition. (See *e.g.* Fingl *et al.*, in *The Pharmacological Basis of Therapeutics*, 1975, Ch. 1 p. 1). It should be noted that the attending physician would know how to and when to terminate, interrupt, or adjust administration due to toxicity, or to organ dysfunctions. Conversely, the attending physician would also know to adjust treatment to higher levels if the clinical response were not adequate (precluding toxicity). The magnitude of an administered dose in the management of the disorder of interest will vary with the severity of the condition to be treated and to the route of administration. The severity of the condition may, for example, be evaluated, in part, by standard prognostic evaluation methods. Further, the dose and perhaps dose frequency, will also vary according to the age, body weight, and response of the individual patient. A program comparable to that discussed above may be used in veterinary medicine.

Depending on the specific conditions being treated, such agents may be formulated and administered systemically or locally. Techniques for formulation and administration may be found in *Remington's Pharmaceutical Sciences*, 18th ed., Mack Publishing Co., Easton, PA (1990). Suitable routes may include oral, rectal, transdermal, vaginal, transmucosal, or intestinal administration; parenteral delivery, including intramuscular, subcutaneous, intramedullary injections, as well as intrathecal, direct intraventricular, intravenous, intraperitoneal, intranasal, or intraocular injections, just to name a few.

For injection, the agents of the invention may be formulated in aqueous solutions, preferably in physiologically compatible buffers such as Hanks's solution, Ringer's solution, or physiological saline buffer. For such transmucosal administration, penetrants appropriate to the barrier to be permeated are used in the formulation. Such penetrants are
5 generally known in the art.

Use of pharmaceutically acceptable carriers to formulate the compounds herein disclosed for the practice of the invention into dosages suitable for systemic administration is within the scope of the invention. With proper choice of carrier and suitable manufacturing practice, the compositions of the present invention, in particular, those
10 formulated as solutions, may be administered parenterally, such as by intravenous injection. The compounds can be formulated readily using pharmaceutically acceptable carriers well known in the art into dosages suitable for oral administration. Such carriers enable the compounds of the invention to be formulated as tablets, pills, capsules, liquids, gels, syrups, slurries, suspensions and the like, for oral ingestion by a patient to be treated.

15 Agents intended to be administered intracellularly may be administered using techniques well known to those of ordinary skill in the art. For example, such agents may be encapsulated into liposomes, then administered as described above. Liposomes are spherical lipid bilayers with aqueous interiors. All molecules present in an aqueous solution at the time of liposome formation are incorporated into the aqueous interior. The
20 liposomal contents are both protected from the external microenvironment and, because liposomes fuse with cell membranes, are efficiently delivered into the cell cytoplasm. Additionally, due to their hydrophobicity, small organic molecules may be directly administered intracellularly.

Pharmaceutical compositions suitable for use in the present invention include
25 compositions wherein the active ingredients are contained in an effective amount to achieve its intended purpose. Determination of the effective amounts is well within the capability of those skilled in the art, especially in light of the detailed disclosure provided herein. In addition to the active ingredients, these pharmaceutical compositions may contain suitable pharmaceutically acceptable carriers comprising excipients and auxiliaries
30 which facilitate processing of the active compounds into preparations which can be used

pharmaceutically. The preparations formulated for oral administration may be in the form of tablets, dragees, capsules, or solutions. The pharmaceutical compositions of the present invention may be manufactured in a manner that is itself known, *e.g.*, by means of conventional mixing, dissolving, granulating, dragee-making, levitating, emulsifying, 5 encapsulating, entrapping or lyophilizing processes.

Pharmaceutical formulations for parenteral administration include aqueous solutions of the active compounds in water-soluble form. Additionally, suspensions of the active compounds may be prepared as appropriate oily injection suspensions. Suitable lipophilic solvents or vehicles include fatty oils such as sesame oil, or synthetic fatty acid 10 esters, such as ethyl oleate or triglycerides, or liposomes. Aqueous injection suspensions may contain substances which increase the viscosity of the suspension, such as sodium carboxymethyl cellulose, sorbitol, or dextran. Optionally, the suspension may also contain suitable stabilizers or agents which increase the solubility of the compounds to allow for the preparation of highly concentrated solutions.

15 Pharmaceutical preparations for oral use can be obtained by combining the active compounds with solid excipient, optionally grinding a resulting mixture, and processing the mixture of granules, after adding suitable auxiliaries, if desired, to obtain tablets or dragee cores. Suitable excipients are, in particular, fillers such as sugars, including lactose, sucrose, mannitol, or sorbitol; cellulose preparations such as, for example, maize 20 starch, wheat starch, rice starch, potato starch, gelatin, gum tragacanth, methyl cellulose, hydroxypropylmethyl-cellulose, sodium carboxymethylcellulose, and/or polyvinylpyrrolidone (PVP). If desired, disintegrating agents may be added, such as the cross-linked polyvinyl pyrrolidone, agar, or alginic acid or a salt thereof such as sodium alginate.

25 Dragee cores are provided with suitable coatings. For this purpose, concentrated sugar solutions may be used, which may optionally contain gum arabic, talc, polyvinyl pyrrolidone, carbopol gel, polyethylene glycol, and/or titanium dioxide, lacquer solutions, and suitable organic solvents or solvent mixtures. Dyestuffs or pigments may be added to the tablets or dragee coatings for identification or to characterize different combinations of 30 active compound doses.

Pharmaceutical preparations which can be used orally include push-fit capsules made of gelatin, as well as soft, sealed capsules made of gelatin and a plasticizer, such as glycerol or sorbitol. The push-fit capsules can contain the active ingredients in admixture with filler such as lactose, binders such as starches, and/or lubricants such as talc or magnesium stearate and, optionally, stabilizers. In soft capsules, the active compounds may be dissolved or suspended in suitable liquids, such as fatty oils, liquid paraffin, or liquid polyethylene glycols. In addition, stabilizers may be added.

Some methods of delivery that may be used include:

- a. encapsulation in liposomes,
- 10 b. transduction by retroviral vectors,
- c. localization to nuclear compartment utilizing nuclear targeting site found on most nuclear proteins,
- d. transfection of cells ex vivo with subsequent reimplantation or administration of the transfected cells,
- 15 e. DNA transporter system.

All publications referenced are incorporated by reference herein, including the nucleic acid sequences and amino acid sequences listed in each publication. All the compounds disclosed and referred to in the publications mentioned above are incorporated by reference herein, including those compounds disclosed and referred to in articles cited
20 by the publications mentioned above.

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All publications cited in the specification are incorporated by reference herein, including drawings and sequences listed in each publication. All the compounds disclosed and referred to in the publications mentioned above are incorporated by reference herein,
25 including those compounds disclosed and referred to in articles cited by the publications mentioned above.

Other embodiments of this invention are disclosed in the following claims.